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SOCIAL LIFE AMONG THE INSECTS[1]

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Lecture V. Parasitic Ants and Ant Guests

THE ants are so favorable for the study of certain phenomena which I have been unable to more than touch on in the preceding lectures that I have set this lecture apart for their fuller consideration. I allude to the phenomena which biologists embrace under the terms "symbiosis" or "mutualism" and "parasitism." Social life may, indeed, be regarded merely as a special form of symbiosis. This term, which signifies the living together of organisms in a balanced, cooperative, reciprocally helpful manner, is commonly applied interspecifically, that is, to partners thus related but belonging to different species, but there is no reason why it should not be applied to the same kind of relations between individuals of the same species, that is intraspecifically. Symbiosis is probably never realized in its ideal form, which would require that each of the partner organisms should render to the other in food or services an exact equivalent of what it receives. So great is the greed of organisms that one member of the partnership usually tends to snatch more than its share of the profits accruing from the association. One member is therefore exploited, while the other becomes correspondingly dependent, that is, parasitic. In some groups of animals symbiotic, or mutualistic relations may thus lapse into parasitism, but it seems to me improbable that parasitism among insects has had such an origin. The common and perhaps exclusive source of the phenomenon among these highly specialized organisms is predatism. In fact, the most typical of parasitic insects are really refined predators, which usually, on growing to their full stature, kill the hosts they have been carefully sparing and, one might say, using as food-getting instruments.

[1] Lowell Lectures.

Since this is not exactly the form of parasitism exhibited by other organisms, such as the tape-worms, certain barnacles and bacteria, I prefer to call it "parasitoidism."

Yet even among the insects there are so many kinds and degrees of dependence on other insects that a concise classification is impossible. The phenomena are extremely diverse and protean, merging and melting into one another in the most bewildering manner. My limited time and the exigencies of exposition therefore compel me to condense and schematize. I am, moreover, dealing with a small fragment of a vast subject. The whole organic world is burdened with parasitism, so shackled and impeded by it that progressive evolution becomes inhibited in every group in which it appears, and the classes that have escaped its paralyzing touch are very few. Professor J. M. Clarke has shown that parasitism made its appearance in marine animals as early as the Cambrian and that it has kept recurring ever since, specializing and leading to "degeneration" and thus robbing group after group of species of all hope of further progress. Although they may persist for ages they are doomed to extinction, and only the independent forms, those that neither lapse into parasitic habits nor waste their vitality in nourishing parasites, stand any chance of becoming the ancestors of future types. We therefore belong to a lineage which, by some rare good fortune, escaped all the culs-de-sac of parasitism—till we became social.

The very conditions of social life tend to facilitate the development of the host and parasite relations. Not only do the members of a society become more tolerant of alien organisms in their midst and even domesticate and breed them, but the nests and domiciles because of the protection they afford, their higher temperature, the stores of food, the refuse even, the helpless young and infirm old they contain—all representing so much nourishment—attract hordes of predators, scavengers, inquilines, guests and parasites in the strict sense of the word. And the crowding together of the social organisms greatly facilitates the interchange of all kinds of small parasites, such as mites, moulds and bacteria from host to host. On the other hand, the members of a society are themselves normally temporary parasites of one another, the young of the adults, the old of the young, and even the whole colony, as a unit, may become a temporary or permanent parasite on the colony of some other species. We noticed cases of this kind among the social wasps and bees, namely, *Vespa arctica* and *austriaca* and the various species of Psithyrus, and we shall find more numerous examples among the ants. I did not have time even to enumerate the alien beetles, flies, etc., that live in the nests

of the social wasps and bees, but they are numerous, and we shall find that the termites are surpassed only by the ants in the number of their parasites.

Although man furnishes the most striking illustrations of the ease with which both the parasitic and host rôles may be assumed by a social animal, his capacities in these directions have been little appreciated by the sociologists. Massart and Vandervelde seem to be the only authors who have attempted to do justice to the matter. Our bodies, our domestic animals and food plants, dwellings, stored foods, clothing and refuse support such numbers of greedy organisms, and we parasitize on one another to such an extent that the biologist marvels how the race can survive. We not only tolerate but even foster in our midst whole parasitic trades, institutions, castes and nations, hordes of bureaucrats, grafting politicians, middlemen, profiteers and usurers, a vast and varied assortment of criminals, hoboes, defectives, prostitutes, white- slavers and other purveyors to antisocial proclivities, in a word so many non-productive, food-consuming and space-occupying parasites that their support absorbs nearly all the energy of the independent members of society. This condition is, of course, responsible for the small amount of free creative activity in many nations. Biology has only one great categorical imperative to offer us and that is: Be neither a parasite nor a host, and try to dissuade others from being parasites or hosts. Of course, this injunction is no more easily obeyed than Kant's famous imperative, of which it embodies the biological meaning, for a parasite always treats its host as a means and not as an end, and the thoroughly parasitized host must abandon all hope of being an end in itself.

I have expressed myself somewhat drastically on human parasitism. If I attempted to utter all my opinions on the subject I should probably not be permitted to survive till the next lecture, even in so tolerant a community as Boston. But so vividly are the development and consequences of biological dependence illustrated by the ants that by confining myself to them, and possibly allowing a hint to escape here and there, you will be able to construct your own analogies. The more striking relations of ants to other organisms are enumerated in the accompanying list. I considered the relations to the Phytophthora (Fig. 78) in the preceding lecture, and our knowledge of the relations to the higher plants is in a state too controversial to admit of satisfactory exposition within the limits of this lecture. We may therefore confine our attention to social parasitism, or the behavior of ants as parasites and hosts of one another and to the myrmecophiles, or animals that use the ants as hosts. Social parasitism is exhibited by two

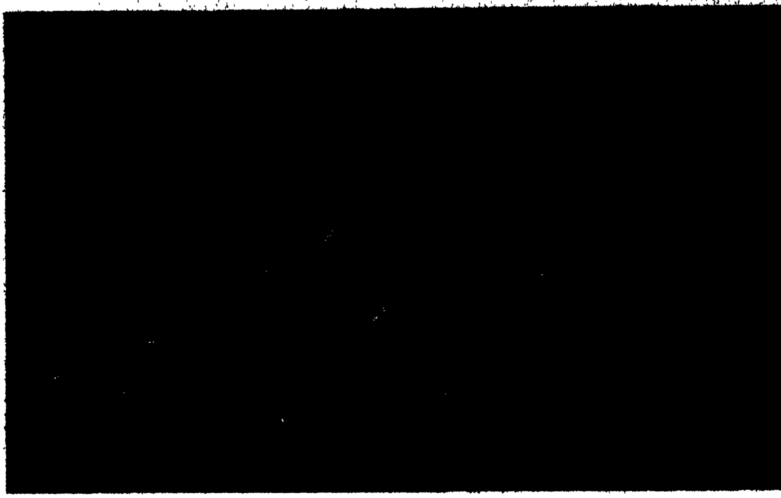

FIG. 78
Ants attending aphids on the roots of grasses and other herbs. (From a drawing by T. Carreras, after E. Step.)

series of species, one in which the parasitic and host colonies occupy separate though contiguous nests and therefore rear their broods in separate chambers, or nurseries, the other in which the two colonies have become so intimately united that they occupy a single nest and bring up their young in common. It will be seen that not only each of these series, but also that of the myrmecophiles begins in predatory (indicated by asterisks) and terminates in definitively parasitic relations.

RELATIONS OF ANTS TO OTHER ORGANISMS

I. SOCIAL PARASITISM (Ants as Parasites)
  A. *Compound Nests* (Broods reared separately)
    *1. Brigandage (Cleptobiosis)
    *2. Thievery (Lestobiosis)
    3. Neighborliness (Plesiobiosis)
    4. Tutelage (Parabiosis, Phylacobiosis)
    5. Hospitality (Xenobiosis)
  B. *Mixed Colonies* (Broods reared together)
    *1. "Slavery" (Dulosis)
    2. Temporary Social Parasitism
    3. Permanent Social Parasitism
II. MYRMECOPHILY (Ants as Hosts)
    *1. Persecuted Intruders (Synechthrans)
    2. Indifferently Tolerated Guests (Synoeketes)
    3. Mess-mates (Commensals)
    4. True Guests (Symphiles)
    5. External Parasites (Ectoparasites)
    6. Internal Parasites (Entoparasites)
III. TROPHOBIOSIS (Relations of Ants to Phytophthora, etc.)
IV. PHYTOPHILY (Relations of Ants to Plants)

The great armies of the nomadic legionary ants to which I alluded in my previous lecture often attack the nests of other ants and carry away and devour all their larvæ and pupæ. This is, of course, pure predatism and is not included in the list because it is hardly a true interspecific association. This is obviously prevented by the itinerant and highly carnivorous behavior of the plunderers. In the compound nests, however, the colonies of the two species occupy stationary nests which are so close together that their galleries may interdigitate or intercommunicate and permit one of the species to enter the nest of the other. Different ant colonies even of the same species are so hostile that their mere existence in such contiguity implies that one of the species is to some extent exploiting the other. That the manner of exploitation differs in different ants will be seen from the following brief account of the various known types of compound nests:

(1) Certain small but aggressive ants, which secure at least a portion of their sustenance by waylaying the foraging workers of another species and snatching away their food, deserve the name of brigands. Such ants naturally make their nests near those of the species they plunder. Thus *Dorymyrmex pyramicus* in our southwestern states often constructs its nests in the clearing surrounding or even on the large mounds of harvesting ants of the genus Pogonomyrmex (Fig. 79).

(2) In cases of what I call "thievery" the exploitation is more

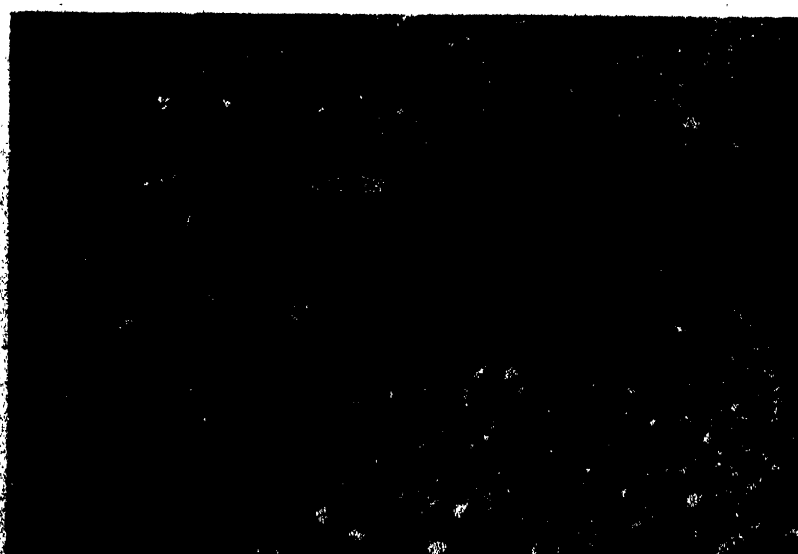

FIG. 79

Mound of agricultural ant (*Pogonomyrmex occidentalis*) bearing a crater (at *a*) of a small brigand ant (*Dorymyrmex pyramicus*).

subtle and efficient. The thief-ants, all of which are subterranean and have very small workers, nest in the earthen walls of populous ant or termite nests, much as the little red house ant (*Monomorium pharaonis*) nests in the walls of our dwellings. The chambers of the two nests are connected by extremely tenuous galleries, excavated, of course, by the thief-ants and permitting them to invade the nests and feed on the brood of their large neighbors, but preventing the latter from entering the nests of the robbers, who are either ignored or overlooked on account of their diminutive size, and therefore carry on their depredations unhindered. The abundance of food which they thus secure enables them to rear very large queens and males, but the workers themselves are condemned to perpetual dwarfishness by their criminal mode of life. The most remarkable thief-ants are found in the large termite nests of the tropics, and the conditions described attain their most extreme expression in the genus Carebara. The workers are minute, pale yellow and blind, the queens and males deeply colored and several thousand times as large as the workers. Arnold has recently suggested that these extraordinary differences in size must make it impossible for the young queen to feed her first brood of workers and hence to establish her formicary in the typical independent manner of other ants. For this reason, when she leaves the parental nest to take her nuptial flight, she carries, attached by their mandibles to the tufted hairs on her feet, several workers, which thus accompany her till she has made her cell in some termite mound, and then take charge of rearing her first brood. On reading Arnold's account I examined a number of females and males of the Ethiopian *Carebara vidua* in my collection and at once found the minute workers attached as he describes. The accompanying sketch (Fig. 80) shows one of the queens carrying two workers. These, of course, also attach themselves to the males that leave the nest at the same time, but as they do not accompany the nest-founding queens and die just after mating, the workers that happen to choose air-planes of the wrong sex also perish.

(3) What, for lack of a better term, I have called "neighborliness," is a very common relationship between two, or more rarely three or even four species of ants living in nests, often with interdigitating but never with intercommunicating galleries, under the same stone or in the same log. Usually the ants of the different colonies, when they happen to meet, are more or less hostile. If one of the species is small and weak it undoubtedly derives some protection from merely living near a large and powerful neighbor, or the feebler may feed to some extent on the refuse of the larger

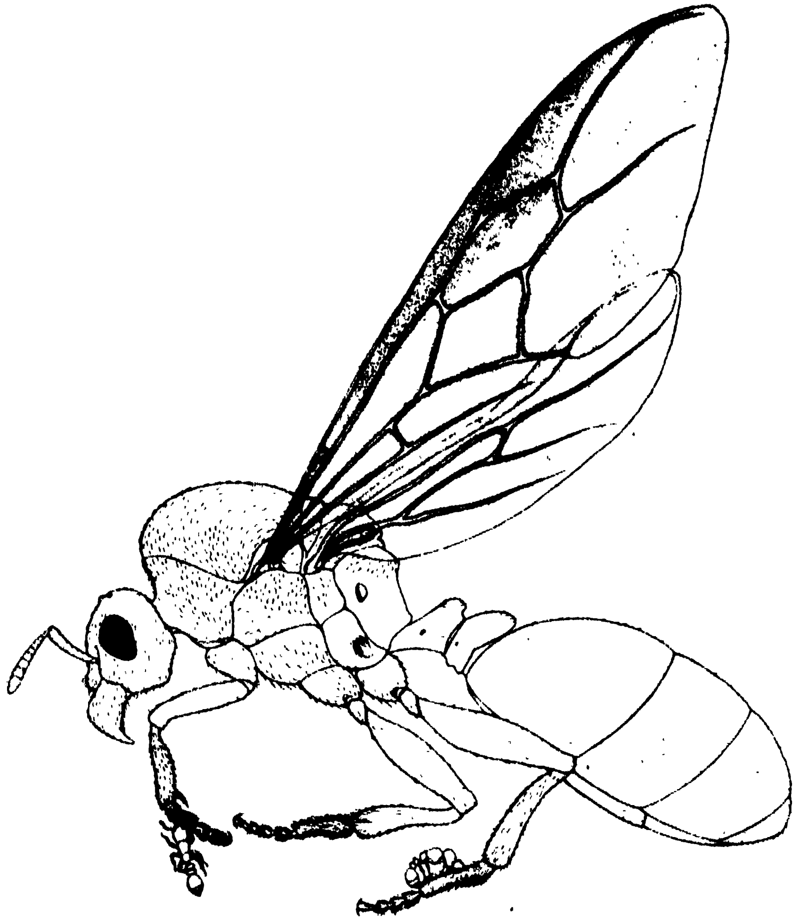

FIG. 80
Winged queen of *Carebara vidua* carrying the minute blind workers of her own species attached to her tarsal hairs.

form. When both species are large and aggressive they may perhaps find it advantageous to present a combined hostile front to the attacks of other ants.

(4) What Forel calls "parabiosis," a word I have translated as "tutelage," seems to be a more definite relation of mutual or unilateral protection. In a typical case which I recently observed in British Guiana, we have two species, a small black Crematogaster (*C. parabiotica*) and a large brown Camponotus (*C. femoratus*) together inhabiting a large ball of earth which they build up around the branch of a tree. In this ball, which Ule calls an "ant-garden," because it supports numerous epiphytes, the Crematogaster inhabits the superficial, the Camponotus the central portions. When it is slightly disturbed the little black ants rush out to attack the intruder, but a more serious disturbance

of the nest at once brings out the battalions of the much larger and extremely vicious brown species. The Crematogaster seem therefore to act as a skirmishing line for the Camponotus. Though the galleries of both species open freely into one another, and though the workers of both forage in long common files on the surrounding vegetation, they nevertheless keep their broods rigidly separated. The tutelary or parabiotic relation is evidently more mutualistic or cooperative than any of the foregoing cases of compound nests.

(5) An interesting series of small species includes the "guest ants" which live in still more intimate relations with other species. One of the best examples is *Leptothorax emersoni* which I first found many years ago associated with the considerably larger *Myrmica canadensis* in bog-like situations on our higher New England hills. The Leptothorax inhabit small chambers at the surface of the Myrmica nest and connect them by means of tenuous galleries with the chambers of their neighbors. The Leptothorax workers spend much of their time in the Myrmica nest where they mount the backs of the workers and assiduously lick their bodies and especially their heads and mouthparts. The Myrmicas seem greatly to enjoy this performance and from time to time reward their little guests with a droplet of regurgitated food. But while the Leptothorax arrogate to themselves the right to mingle freely with the Myrmicas and to flatter them into regurgitation, they resent the intrusion of the Myrmicas into their own habitations and insist on bringing up their own brood in perfect seclusion. Under natural conditions the Leptothorax are never seen to take any food, except from the surfaces and crops of their hosts, but if kept for some time by themselves in an artificial nest, they learn to eat honey and insects like other ants. And if both species are kept together in a glass nest without earth and therefore without materials for making separate chambers, the Leptothorax eventually though very reluctantly permit the Myrmicas to mingle the broods of both species and a true mixed colony is formed.

The ants that live in the various compound nests are not closely allied but belong to different genera or even subfamilies, a fact which may help to explain why they occupy separate nests and do not bring up their broods in common, for the rearing of the brood is a very delicate operation and would be apt to differ considerably in unrelated species. We may therefore be prepared to find that mixed colonies are formed only by closely allied species, *i. e.*, either by those belonging to the same genus or to closely allied genera, and this proves to be the case. But before considering the

various types of mixed colonies, two facts must be emphasized: First, many ants are fond of kidnapping the larvæ and pupæ belonging to other colonies of their own or allied species. Frequently these kidnapped young are devoured, but in well-nourished colonies they may be permitted to complete their development and the emerging workers may be adopted as *bona fide* members of the colony, even if they belong to a different species. It is therefore possible to produce a mixed colony artificially by giving a colony the mature brood of some other species. In this manner Miss Fielde succeeded in inducing species belonging even to very different subfamilies to live together in perfect amity. It is also interesting to observe that ants thus reared in the colony of an alien species may be very hostile to their own sisters that have been left to grow up in the parental nest. Second, the mixed colonies found in nature are not in the first instance produced by a mere kidnapping of the brood of an alien species, but by the young queen of a parasitic species, that is unable to start a colony independently, invading the nest of another species, which then becomes the host. The behavior of the invading parasite and the

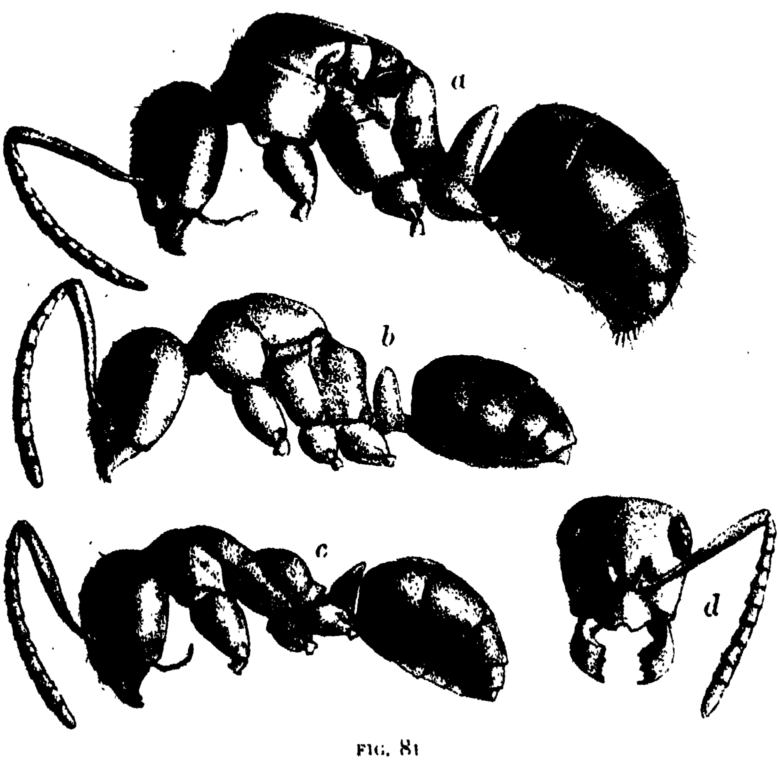

FIG. 81
Blood-red slave-maker (*Formica sanguinea*) in profile. *a*, Queen, with wings and legs removed; *b*, pseudogyne; *c*, worker; *d*, head of same from above, showing the characteristic notch in the clypeus.

host colony differ in different species, but in nearly all the observed cases the host queen, if present, is eventually killed and her place is taken by the alien intruder. Since the queen ant is really the reproductive organ of the colony considered as a superorganism, the host colony may be said to be castrated and its sterile worker personnel is constrained to devote all its energies to rearing the brood which is forthwith produced by the fecund parasite. With these general statements in mind we may turn to the three types of mixed colonies, those of the slave-makers, the temporary and permanent social parasites:

(1) The peculiar phenomena known as slavery, or dulosis, which occur in two genera of Formicinæ, Formica and Polyergus, and two genera of Myrmicinæ, Strongylognathus and Harpagoxenus, represent three phylogenetic stages, a primitive stage in *Formica sanguinea*, a culminating stage in Polygergus and a degenerate or evanescent stage in Strongylognathus and Harpagoxenus. The "blood-red slave maker," *F. sanguinea* (Fig. 81), is a common but rather local red ant, with black or brown gaster and is represented by numerous subspecies and varieties ranging over northern Europe, Asia and North America. It can be readily distinguished from the other species of the genus, at least in the Old World and the eastern United States, by the pronounced notch in the clypeus or small shield at the anterior end of the head. The worker and queen look as if they were hare-lipped. *Sanguinea* is one of the most intelligent of ants and therefore one of the most interesting to keep in artificial nests. Its habits were first studied more than a century ago by Pierre Huber, the son of the blind François Huber, and have ever since commanded the attention of myrmecologists, because its armies of workers make periodical forays on the colonies of the common black *Formica fusca*, carry the worker larvæ and pupæ into their nest and permit many of them to emerge and become members of their colony. Thus the colony is mixed, and the black individuals, on account of their color and provenience, have been called "slaves." It is evident, however, that this term is inappropriate, for a slave is "a man who is the property of another, politically and socially at a lower level than the mass of the people, and performing compulsory labor" (Nieboer), and none of these distinctions applies to the *fusca* workers in the *sanguinea* nest. They are more properly called "auxiliaries" (Hilfsameisen), but I shall use the old term on account of its brevity. At least one of the subspecies of *sanguinea* (*aserva*) does not make slaves, and the colonies of some of the other forms give up the habit after a time, for the *sanguinea* colony, when once established, is quite able to lead an independent

life. Darwin and others offered various explanations of the peculiar slave-making habit of *sanguinea*, but its meaning remained obscure till 1904 when I found that it had its origin in the behavior of the young queen. She is quite unable to found a colony independently and therefore, after her marriage flight, may adopt one of three courses: she may return to the nest in which she was reared or enter some other *sanguinea* nest, or she may invade a nest of *F. fusca*. As the first and second courses are sometimes adopted by other ants and do not lead to the formation of mixed colonies, they need no further consideration in this place and we may confine our attention to the last. As soon as the *sanguinea* queen invades a *fusca* colony, she becomes greatly excited and interested in the brood, seizes and collects in a small pile as many pupæ as she can snatch up and mounts guard over them. She slays any *fusca* workers that are bold enough to attempt to regain their property and is therefore soon left in undisputed possession of her plunder. Eventually *fusca* workers emerge from the cocoons and at once assume a friendly attitude towards the queen, feed her by regurgitation and behave towards her as if she were their own mother. She begins to lay eggs and the resulting larvæ are fed and reared by the black workers, so that when the *sanguinea* emerge a mixed colony is established. These workers show that they have inherited their mother's proclivities by kidnapping the brood of neighboring *fusca* colonies, but they do this as an army and carry the *fusca* brood to their nest. In some colonies, as I have stated, this kidnapping or slave-making proclivity may disappear after a time, and in *aserva* it seems to disappear very early or perhaps is not even inherited by the workers. In such cases, therefore, the personnel of old colonies may be made up entirely of *sanguinea* after the batch of *fusca* workers kidnapped and reared by the queen has died of old age. It is evident that slavery is at bottom a form of predatism and has its origin in the inability of the young queen to establish a colony without the aid of workers. Unlike the great majority of ant-queens, she has been unable to store enough food in her body to stand the strain of long fasting and nourishing her first brood. In another sense she is, of course, a parasite and the *fusca* workers represent the host. Owing to the fact that the colony may eventually cease to increase its worker personnel by the kidnapping of *fusca* brood, we may call this type of slavery temporary, acute or facultative.

The species of Polyergus, or "amazons," as they were called by Pierre Huber, have much the same distribution as *sanguinea* and have the same species of Formica as slaves, but their method of securing the latter is more highly perfected. The amazons

FIG. 82
a, Worker of *Polyergus lucidus*, the "shining amazon," a permanent slave-maker of the Eastern United States; *b*, head of same, showing the sickle-shaped mandibles.

are very beautiful red ants (except the Japanese *P. samurai*, which is black), and their mandibles are slender and sickle-shaped and perfectly adapted to fighting but of no use for digging in the earth or capturing food (Fig. 82). Hence these insects are unable to make nests or even to feed themselves or care for their own young, but are absolutely dependent on their slaves. Like *sanguinea*, the amazons make periodical forays, which for some unknown reason are always carried out in the afternoon, but their armies show a more perfected tactical organization and the subjugation and plundering of the *fusca* colonies are effected with much greater dispatch and precision—one might say with the most consummate *éclat*. At the approach of the amazons the *fusca*

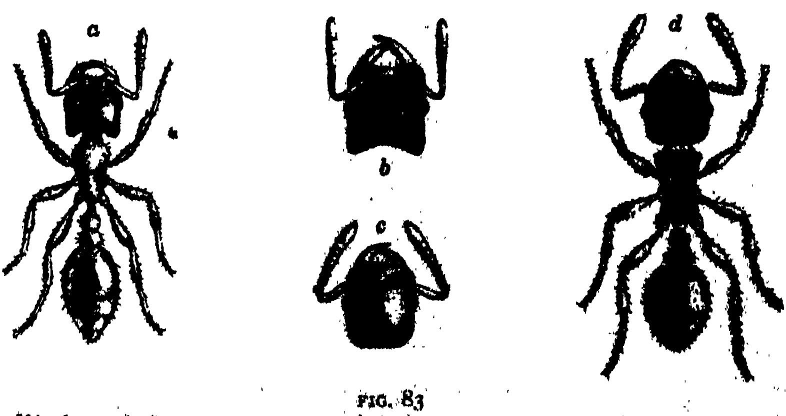

FIG. 83
a, Worker of *Strongylognathus testaceus*, a degenerate slave-maker of Europe; *b*, head of female of same; *c*, head of worker of *S. huberi*, an allied species; *d*, worker of the pavement ant (*Tetramorium caespitum*), the host of the species of Strongylognathus.

workers usually flee in dismay, but if they offer any resistance the amazons pierce their heads with the sickle-shaped mandibles. The young on emerging from the kidnapped pupæ excavate the nest, feed the Polyergus and bring up their brood but do not accompany the armies on their raids. The initial stages in founding the colony have been studied by Emery, who found that the young Polyergus queen secures adoption in some small, weak *fusca* colony after killing its queen by piercing her head. She then produces her brood which will later make the slave-raids on the *fusca* colonies. Since this raiding proclivity never lapses even in old colonies, Polyergus is to be regarded as a chronic, or obligatory slave-maker. An amazon crimson on a field sable with the device "*stultus sed pugnax*" might be an appropriate coat-of-arms for some of the military castes that have flourished during the course of human history.

In Europe there are several species of the interesting genus Strongylognathus (Fig. 83*a*-*c*), which have sickle-shaped mandibles like Polyergus and always live in the colonies of the common pavement ant, *Tetramorium caespitum* (Fig. 83*d*). Our fragmentary knowledge indicates that we have here some of the degenerate or evanescent stages of slavery. The workers of *S. rehbinderi* and *huberi* seem still to make forays on Tetramorium colonies and to carry home their brood, and Kutter has recently shown that *S. alpinus*, a form I discovered some years ago near the head-waters of the Visp, within sight of the Matterhorn, makes nocturnal slave raids and is accompanied by its slaves, which do most of the fighting and carry home the brood of their own species. In this case the slaves are really the masters and seem to use the Strongylognathus merely as a means of disconcerting or terrifying the colonies of *cæspitum* whose brood they are bent on kidnapping. Finally, *S. testaceus*, the best-known species of the genus, no longer makes forays and is tending to lose its worker caste. Wasmann, Mrázek, Forel and I have found that colonies of *cæspitum* infested by this species may retain the host queen. In order to establish her colony, therefore, the young *testaceus* queen probably associates herself with a young, nest-founding *cæspitum* queen. In the mixed colonies of other species of Strongylognathus the host queen appears to be eliminated as in the colonies of *sanguinea* and Polyergus.

(2) In 1904 I detected another method of forming mixed colonies, which I called temporary, although I might have called it acute social parasitism. It is practiced by a number of ants, especially by several North American species of Formica that have unusual queens. In some species they are peculiarly colored or

furnished with long yellow hairs, in others they are extremely small, smaller even than the largest workers (Fig. 84). The young queen of these ants enters the nest of another Formica belonging to the *fusca* or *pallide-fulva* group and is very apt to be adopted, probably on account of her smaller size or other physical attractions. The fate of the host queen in such invaded nests has not been ascertained but she is probably killed by her own workers. The parasite then proceeds to produce her brood, which is reared by the host workers, and a mixed colony results. As there is no inclination on the part of the queen's offspring to plunder other nests of the host species, and as all the host workers die off in the course of a few years, a pure colony of the parasitic species is left behind and may grow to be very populous and aggressive, without showing any signs of its parasitic origin—a beautiful analogue of some human institutions, which after starting in humble and cring-

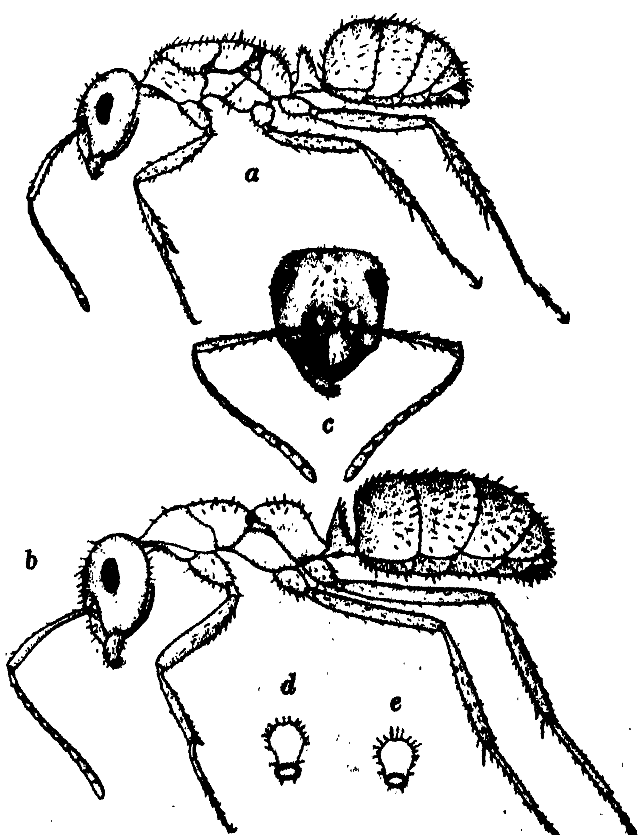

FIG. 84

A temporary parasite (*Formica microgyna*). *a*, queen, with wings removed; *b*, large worker drawn to same scale; *c*, head of same; *d* and *e*, petiole of worker and queen seen from behind.

ing parasitism have come to acquire during the centuries a most exuberant and insolent domination. Our common mound-building ant (*Formica exsectoides*) is one of these successful temporary parasites which starts its opulent colonies with the aid of the ubiquitous *F. fusca* var. *subsericea*. Since my observations were published many European Formicas, including the well-known mound-building *rufa*, and ants of several other genera (Lasius, Bothriomyrmex, Crematogaster, etc.) in various parts of the world have been found to be temporary social parasites. One of the most interesting of these is the Dolichoderine *Bothriomyrmex decapitans* which Santschi observed in Tunis. The young queen, on descending from her marriage flight, wanders about on the ground till she finds the nest of a *Tapinoma nigerrimum* colony, when she permits herself to be seized and "arrested" by its workers. These then proceed to drag her into their burrow by her legs and antennæ. After entering the nest the parasite may be attacked from time to time by the workers, but she takes refuge on the brood or on the back of the larger Tapinoma queen. In either of these positions she seems to be quite immune from attack, probably because her own odor is overlaid by that of the brood or the host queen. Santschi observed that the parasite often spends long hours on the back of the Tapinoma queen and that while in this position she busies herself with sawing off the head of her host! By the time she has accomplished this cruel feat, she has acquired the nest-odor and is adopted by the Tapinoma workers in the place of their unfortunate mother. The parasite thereupon proceeds to keep them busy bringing up her brood. They eventually die of old age and the nest then becomes the property of a thriving, pure colony of *Bothriomyrmex decapitans*.

(3) There are more than a dozen genera of ants from various parts of the world, which may be classed as permanent, or chronic social parasites. They have all completely lost the worker caste so that in this respect they closely resemble the parasites among the social wasps and bees. The young queens enter the nests of other ants and secure adoption, like the queens of the temporary social parasites. The host queen seems to be regularly assassinated by her own workers. At least this has been observed by Santschi in the case of *Wheeleriella santschii*, which lives in the nests of the common North African *Monomorium salomonis*. After fecundation the *Wheeleriella* queen roams about over the surface of the soil in search of a Monomorium nest. When near the entrance of one of them she is "arrested," to use Santschi's expression, by a band of Monomorium workers, which tug at her legs and antennæ and draw her into the galleries. Sometimes she may be

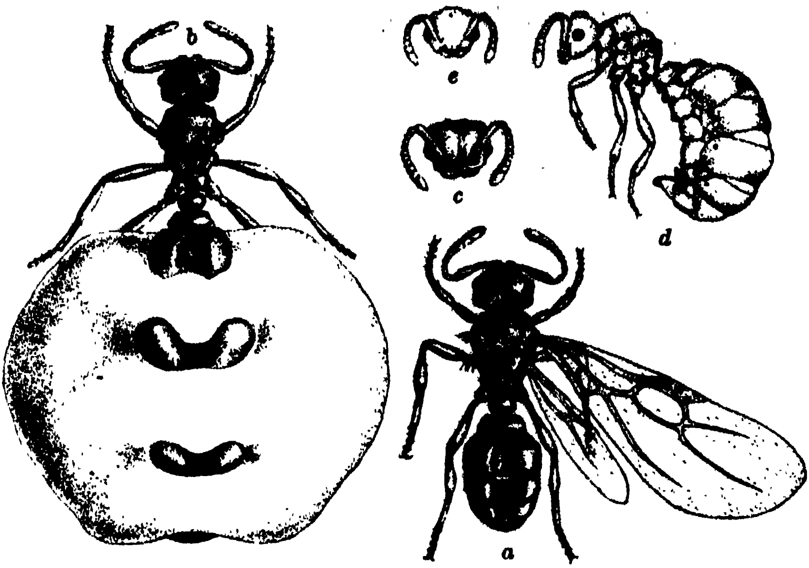

FIG. 85
A workerless, degenerate, permanent social parasite (*Anergates atratulus*) of Europe. *a*, virgin queen; *b*, old, egg-laying queen with enlarged gaster; *c*, head of same from front; *d*, male, which is wingless and pupoidal; *e*, head of same.

seen to dart suddenly into the entrance of her own accord and is arrested within the nest. There are no signs of anger on the part of the Monomorium, and she is soon permitted to move about the galleries unmolested. The workers then begin to feed and adopt her and in the course of a few days she lays her first eggs, which are accepted and cared for by the host. The parasite pays no attention to the much larger Monomorium queen, but the latter is eventually assassinated by her own workers. Other species, like the famous *Anergates atratulus* (Fig. 85) of Europe and the recently discovered *Anergatides kohli* of the Congo, are much more highly modified and represent the last stages of parasitic degeneration. In the former, which lives with *Tetramorium cæspitum*, the queen is small and winged (Fig. 85*a*), but after deälation and adoption her gaster swells enormously with eggs till she resembles an old termite queen (Fig. 85*b*). The male (Fig. 85*d*) is wingless and pupa-like and unable to leave the nest so that mating takes place between brothers and sisters ("adelphogamy" of Forel). The conditions in Anergatides, which is a parasite of *Pheidole melancholica*, are somewhat similar. In the workerless parasites the offspring of the intrusive queen are, of course, all males and females and are produced during the life-time of the host workers. The colonies are therefore mixed throughout their existence which is necessarily terminated by the death of the host.

While all myrmecologists now agree in recognizing the three types of social parasitism and their origin in the behavior of the young queens, there is still disagreement in regard to their phylogenetic derivation. I at first believed that they had all had their inception in the passive adoption of insufficiently endowed, young queens by colonies of their own species, and Wasmann has consistently adhered to this view. Emery and Viehmeyer, however, see in the aggressive, predatory behavior of the *sanguinea* queen a stage from which temporary and permanent social parasitism may be more naturally derived. I am now inclined to believe that these investigators are nearer the truth and that the adoption of queens by colonies of their own species is a distinct phenomenon, which may readily lead to the formation of new colonies by a kind of swarming, analogous to that of many social bees and wasps, but not to the series of parasitic developments which we have been considering.

All the parasitic ants are rare or local. The permanent, or chronic social parasites, especially, are so very scarce that they must be on the very verge of extinction—a fact which shows that parasitism, so far as the race is concerned, is anything but a promising or profitable business. But even the individual parasite buys its rare successes very dearly, for it must often run the gauntlet of great resistance and animosity on the part of a too healthy host and must at the same time carefully avoid seriously injuring that host and thus bringing about its own destruction. Parasitism in the queen ant may, indeed, be regarded as a kind of compensation or overcompensation for her inability to rear a brood of workers. One is reminded of the overcompensations (megalomania) resorted

PERMANENT SOCIAL PARASITES (ANTS WITHOUT WORKERS)

PARASITES	HOSTS	HABITAT	ANCESTRAL GENUS
Sympheidole elecebra	*Pheidole ceres*	Nearctic	Pheidole
Epipheidole inquilina	*Pheidole ceres*	Nearctic	Pheidole
Paropheidole belti	(?) *Pheidole sp.*	Malagasy	Pheidole
Sifolinia lauræ	(?) *Pheidole sp.*	Palearctic	Pheidole
Anergatides kohli	*Pheidole melancholica*	Ethiopian	Pheidole
Wheeleriella santschii	*Monomorium salomonis*	Palearctic	Monomorium
Wheeleriella adulatrix	*Monomorium subnitidum*	Palearctic	Monomorium
Wheeleriella wroughtoni	*Monomorium indicum*	Palearctic	Monomorium
Epœcus pergandei	*Monomorium minimum*	Nearctic	Monomorium
Epixenus andrei	*Monomorium venustum*	Palearctic	Monomorium
Epixenus biroi	*Monomorium creticum*	Palearctic	Monomorium
Myrmica myrmoxena	*Myrmica lobicornis*	Palearctic	Myrmica
Hagioxenus schmitzi	*Tapinoma erraticum*	Palearctic	Monomorium
Anergates atratulus	*Tetramorium cæspitum*	Palearctic	(?) Tetramorium
argentina	(?) *Mœllerius balzani*	Neotropical	Mœllerius
nuptialis	*Plagiolepis custodiens*	Ethiopian	Plagiolepis

to by some human being with pronounced inferiority complexes. Was it an inkling of this that led the ancients to make Hercules the tutelary deity of parasites? That the parasitic queen's inability has been acquired and fixed during the past history of the species is suggested by the singularly close genetic relations of the parasites to their hosts. In the great majority of cases, as indicated in the accompanying list, the parasite belongs either to the same genus as its host or to a genus descended from that of its host. This is equally clear from detailed lists of the other parasitic ants, wasps and bees and shows that the parasite originally led an independent life but took to exploiting some common, allied species of the same genus. Probably the exploitation was at first predatory as it still is in certain Psammocharid wasps and *Formica sanguinea*, because food was more expeditiously secured by such tactics. In the course of time the parasite's adaptations to its host became increasingly refined and were reflected in its structure as generic distinctions, as we see, *e. g.*, in the species of Polyergus, which are obviously modified Formicas. The descent to Avernus became steeper and more slippery, as the parasite, yielding to inertia, became chronically and abjectly dependent on its host and condemned itself to physiological and numerical inferiority ("misère physiologique"). The next stage is extinction, after a longer or shorter period of hopeless specialization ("degeneration"). This or a very similar story has been so often repeated in all the classes of the animal and plant kingdoms that the number of forms which during geological time have descended to the *limbus parasitorum* must be considerable.

Having considered the ants as parasites and hosts of one another, we may now turn to the cases in which they act as the hosts of insects belonging to very different orders, the myrmecophiles, or ant-guests. Here we enter on a vast and very intricate subject to which I shall be unable to do justice in the short time at my disposal. Fully 2,000 species of myrmecophiles have been described, and no doubt the number will be more than doubled when the nests of the many species of tropical ants have been carefully explored. The myrmecophiles include not only members of nearly all the different orders of insects but also many spiders, mites, millipeds and land-crustaceans—a weird, one might almost say demoniacal, horde of creatures, which have been induced to live in more or less intimate and maleficent relations with the ants by the obvious advantages of the association. Ant nests furnish admirable hiding or lurking places and are at night and during the winter months somewhat warmer than the surrounding soil. They often contain quantities of food or refuse, and the helpless brood,

callow and injured ants may be stealthily devoured. Furthermore, the ants may be wheedled into adopting and feeding alien insects, as if they were their own young or ants of the same species. All the forms of exploitation, therefore, from predatism, adoption and domestication to external and internal parasitism have been developed by the myrmecophiles. It may be said that these creatures have searched out and taken advantage of every vulnerable point in the ant's structure and behavior, just as every human idiosyncrasy, frailty and virtue has been exploited by some cunning human parasite.

There are two reasons why we must consider the myrmecophiles in these lectures. First, many of them live only with particular ants and really form a constituent though not an essential part of their colonies, for although they are not present in all colonies, they can not exist apart from the ants except while migrating from one nest to another. They are, in fact, a more integral component

FIG. 86

Larvæ and pupæ of a ponerine ant (*Pachycondyla montezumia*) and its commensal (*Metopina pachycondylae*). The Pachycondyla larvæ marked *x* have each a Metopina larva around the neck; *s*, isolated Metopina larva; *v*, Metopina puparium; *u*, cocoon of Pachycondyla.

of the colony in which they occur than are the domestic animals in the human community. Many of our domestic animals are still able to return to an independent, feral life, but this is impossible for the more typical and highly specialized ant-guests. Second, the ant-guests afford a very striking, indirect or pathological demonstration of the extraordinary intensity of the brood-nursing propensities of ants. Any insect possessed of the glandular attractions, which I shall presently describe, can induce the ants to adopt, feed and care for it and thus become a member of the colony, just as an attractive and apparently well-behaved foreigner can secure naturalization and nourishment in any human community. But the procedure among the ants is more striking, because the foreigners are so very foreign, that is, belong to such alien and heterogeneous groups. Were we to behave in an analogous manner we should live in a truly Alice-in-Wonderland society. We should delight in keeping porcupines, alligators, lobsters, etc., in our homes, insist on their sitting down to table with us and feed them so solicitously with spoon-victuals that our children would either perish of neglect or grow up as hopeless rhachitics.

Although every species of myrmecophile has its own methods of securing food and lodgings in the ant nest I shall describe only a few examples to illustrate the exploitation of the trophallactic habit.

(1) There are probably several myrmecophiles that steal the food given to the larva, but the only case that has been adequately described is the larva of a small fly, *Metopina pachycondylæ*, which I found many years ago in Texas infesting the nests of a Ponerine ant, *Pachycondyla montezumia* (Fig. 86). This ant feeds its larvæ in a very primitive manner with pieces of insects and thus exposes itself to the inroads of the Metopina. Its small larva clings to the neck of the ant larva by means of a sucker-like posterior end and encircles its host like a collar. Whenever the ant larva is fed by the workers with pieces of insect placed on its trough-like ventral

FIG. 87

Atelura formicaria about to snatch the droplet of food that is being regurgitated by one *Lasius mixtus* worker to another. (After C. Janet.)

surface, within reach of its mouthparts, the larval Metopina uncoils its body and partakes of the feast; and when the ant larva finally spins its cocoon it also encloses the Metopina larva within the silken web. The commensal, however, moves to the caudal end of its host and forms a small flattened puparium which is applied to the wall of the cocoon. This is obviously an adaptation for preventing injury from the jaws of the worker ants when the cocoon is being opened and the callow extracted from its anterior end. The ant hatches before the Metopina and the empty cocoon, with the puparium concealed in its posterior pole, is carried to the refuse heap. Here the fly emerges and escapes from the cocoon by the opening through which its host emerged. The Metopina consumes so little food and is so considerate of its host that it can hardly be said to produce any injurious effect on the colony; at any rate the larvæ which have borne commensals develop into perfectly normal workers. The ants clean the commensals when they are cleaning their own progeny and show no signs of being aware of their presence in the nest.

(2) *Lepismina* (*Atelura*) *formicaria* (Fig. 87) is a small, primi-

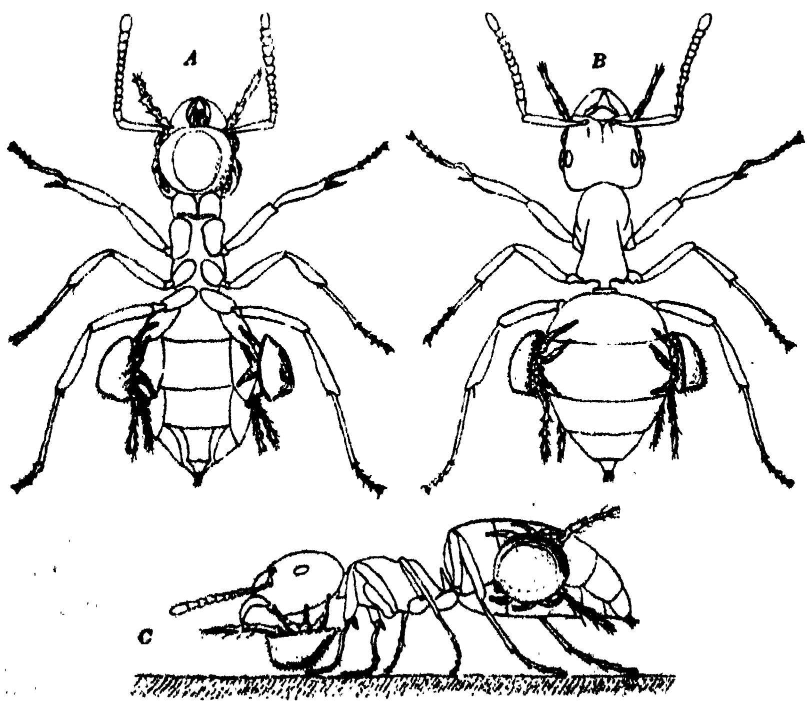

FIG. 88

Lasius mixtus worker carrying three symmetrically oriented mites (*Antennophorus pubescens*). *A*, ventral; *B*, dorsal; *C*, lateral view. (After C. Janet.)

tive insect which lives in the nests of *Lasius mixtus*. Its body tapers rapidly behind and is covered with slippery scales so that it is not easily caught by the ants. It is, moreover, extremely agile and circumspect, because it has not succeeded in ingratiating itself with its hosts. Janet, after providing a colony of *Lasius mixtus* with honey, was able to make the following observations on the behavior of the insect: "From the instant that the first foragers returned to the nest, the Lepismina showed by their excitement that they perceived the odor of honey. Soon a considerable number of ants were grouped in couples for the purpose of regurgitating. They elevated their bodies slightly and often raised their fore legs, thus leaving a vacant space under their heads. As soon as a Lepismina came near such a couple, it thrust itself into the space, raised its head, suddenly snapped up the droplet that was passing in front of it and made off at once as if to escape merited pursuit. But the ants standing face to face are not free enough in their movements even to threaten the audacious thief, who forthwith proceeds to take toll from another couple and continues these tactics till his appetite is appeased."

(3) A more subtle method of obtaining regurgitated food is adopted by the large mites of the genus Antennophorus (Fig. 88), which have been studied by Janet, Wasmann, Karawaiew and myself. These mites, which have conspicuously long fore legs and attach themselves to the bodies of the workers, whether present in odd or even number, always orient themselves in a symmetrical position with respect to their host. When only one Antennophorus is present it clings to the gula, or chin of the ant, with its fore legs directed towards the ant's mouthparts. When two are present, there is one on each side of the head or one on each side of the gaster; in the former case the antenniform appendages are directed towards the anterior, in the latter towards the posterior end of the ant's body. When there are three mites, one attaches itself to the chin and the two others to the sides of the gaster. Four place themselves in pairs on the sides of the head and gaster. If six are present, which rarely happens, four are arranged in pairs on the sides of the head and gaster while of the two remaining individuals, one attaches itself to the chin, the other to the mid-dorsal surface of the gaster. Janet believes that these symmetrical arrangements are for the purpose of balancing the burden and thus making it easier for the ant to carry. When attached to the head the mite obtains its food by drinking the regurgitated droplet as it is being passed to or from the mouthparts of the host, or it titillates the ant with its antenniform legs and induces her to regurgitate for its special benefit. The mites attached to the gaster obtain their

food by stroking other ants in the vicinity or by reaching out and partaking of the droplets as they pass from one ant to another. The ants try to rid themselves of the parasites when they first attach themselves, but after they have taken up their definitive, symmetrical positions, they seem to be tolerated with indifference.

Most of the species of Antennophorus have been described from Europe, but I have found two species (*donisthorpei* and *wasmanni*) rather common near the Arnold Arboretum in Boston. They live in essentially the same manner as the European Antennophori with our small yellow ants of the genus Lasius, and its subgenus Acanthomyops. All these Lasii are hypogæic and devote themselves to attending snow-white plant-lice and mealy-bugs on the roots of our forest trees, and since the mites occur only with these ants it would seem that they, the plant-lice, the mealy-bugs, the mites and the forest trees are all so many members of a peculiar, subterranean association, or biocoenose. The plant-lice and mealy-bugs pump the juices out of the plants and pass on to the soliciting ants the unassimilated portions in the form of honeydew, some of which the ants regurgitate to the mites that ask them for it by aping with their long, hairy forelegs the antennary movements of the hungry ants. In other words, the ants serve as cup-bearers, distributing to one another and to the indolent, sedentary Antennophori the nectar which the tapster plant-lice and mealy-bugs keep drawing from their vegetable hosts. Owing to this interesting biocoenotic arrangement the worker Lasii do not have to come to the surface of the ground to seek their food. The eyes of the

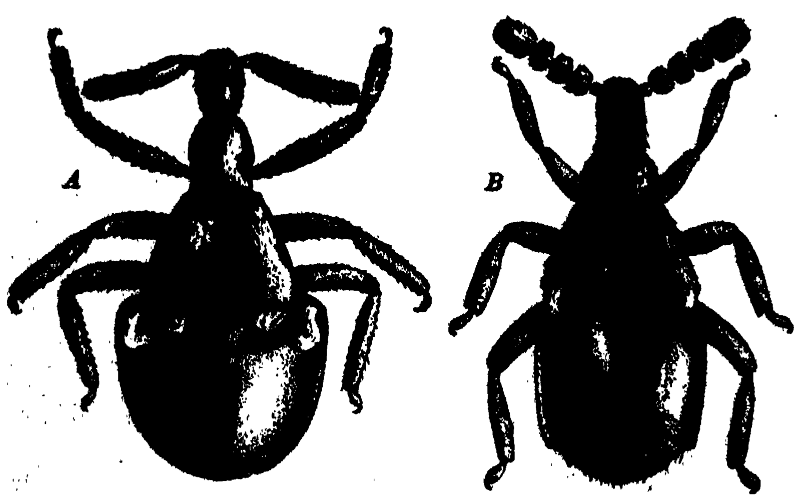

FIG. 89

A, Adranes lecontei of North America, and *B, Claviger testaceus* of Europe, two guest beetles, with golden yellow trichomes at the tips of their wing-cases and at the base of the abdomen.

workers have therefore become so minute that their visual powers must have nearly or quite disappeared. Perhaps we can best appreciate the relations of the ants to the mites if we fancy ourselves blind, condemned to live in dark cellars and continually occupied with pasturing and milking fat, sluggish cows, yielding quantities of strained honey instead of milk. Then let us suppose that occa-

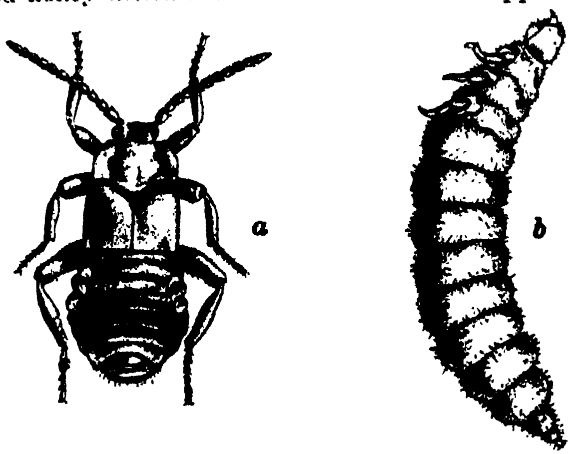

FIG. 90
a, A European guest-beetle (*Lomeschusa strumosa*) and *b*, its larva, which live with colonies of the blood-red slave-maker (*Formica sanguinea*).

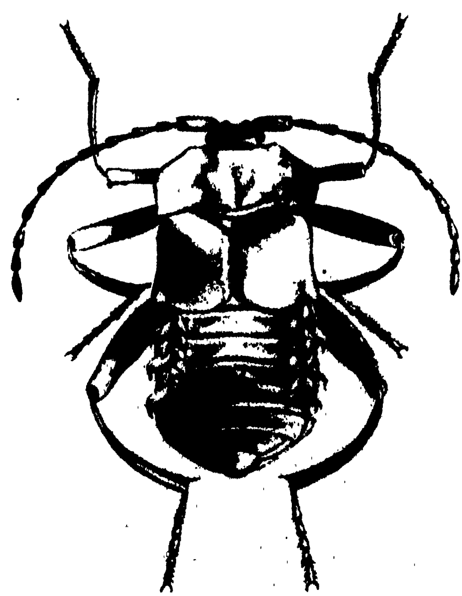

FIG. 91
Xenodusa cava, a North American beetle which breeds in the nests of Formica during the summer and passes the winter in the nests of Camponotus. Note the tufts of trichomes along the sides of the abdomen.

sionally there alighted on our cheeks or backs small creatures which, by placing themselves in positions symmetrical to the median longitudinal axis of our bodies, took great care not to annoy us, and stretched forth to us from time to time small, soft hands, like those of our friends, begging for a little of the honey, should we not under the circumstances treat these little Old Men of the Sea with much lenity and even with something akin to affection?

(4) The behavior of the myrmecophiles I have been considering is simple and transparent compared with that of the true ant-guests or symphiles, which are really the *élite* of all the insects that live in ant colonies. They comprise several hundred species of beetles belonging to a number of natural families but showing a very singular, convergent agreement in certain characters, such as a deep, oily red color and peculiar tufts of golden yellow hairs, or trichomes on various parts of their bodies (Fig. 89). Their antennæ and mouth-parts, too, are in many cases peculiarly modified, the former for soliciting, the latter for receiving regurgitated food. The trichomes surround the openings of singular glands, the aromatic, volatile secretions of which flow along the hairs and are licked off by the ants. So inordinately fond are the ants of these secretions that they cherish the beetles, feed them and carry them to safety when the nest is disturbed or to new nests when the old ones have to be abandoned. The beetles breed in the colonies and their larvæ are often treated with even greater solicitude than the ant larvæ.

FIG. 92
Worker of the blood-red slave-maker, *Formica sanguinea*, feeding its guest beetle, *Lomechusa strumosa*. (After H. K. Donisthorpe.)

Probably the most remarkable of these true guests are the Lomeschusini, which have been studied by Wasmann for more than 30 years. They belong to the rove-beetles, or Staphylinidæ and comprise only three genera: Lomeschusa (Fig. 90) and Atemeles, peculiar to Europe and Northern Asia, and Xenodusa (Fig. 91), known only from the United States and Mexico. The species of Atemeles and Xenodusa have two hosts, those of the former living during the summer and breeding in Formica colonies but hibernating in colonies of Myrmica, the latter also breeding with Formica but hibernating with our large carpenter ants of the genus Camponotus. Lomeschusa, on the other hand, has only one host, *Formica sanguinea*, with which it lives throughout the year. The adult beetles of all three genera look much alike. They have long, mobile antennæ, short wing-cases and a voluminous abdomen, which can be curled up over the thorax and is provided on each side above with a segmental series of beautiful golden trichomes. Atemeles and Xenodusa beg their food from the ants by stroking their cheeks with the fore feet. Their larvæ are active, have long legs and employ the same method as the beetles in persuading the ants to regurgitate. They also devour the defenseless Formica larvæ. The adult Lomeschusa is more passive in its behavior and uses its antennæ in soliciting food (Fig. 92). Its larvæ (Fig. 90*b*) have very short legs and are unable to run about but lie among the ant brood. They eat the brood but are also fed by regurgitation. In all probability they secrete fatty exudates which are greatly appreciated by the ants. At any rate, the ants seem to prefer the Lomechusa larvæ to their own, or perhaps regard them as unusually promising ant larvæ. In consequence of this infatuation the Lomechusa larvæ often destroy the greater part of the brood, so that in *sanguinea* colonies heavily infested with the parasites the queen larvæ develop abnormally. Either these larvæ are neglected, or the ants actually endeavor to convert them into workers, because they feel that this caste is inadequately represented in the colony. But whatever be the treatment of the queen larvæ, they develop into pathological adults, known as "pseudogynes" (Fig. 81*c*)—abortive creatures, resembling workers in size and in the shape of the head and gaster, but with a more voluminous and convex thorax, approaching that of the queen. They are paler than the normal workers and very lazy, cowardly and incompetent. Usually they constitute 5 to 7 per cent., less frequently 20 per cent. or more, of the personnel of an infested *sanguinea* colony. Their appearance in a nest indicates that the colony is in a diseased condition and on the road to extinction, as the result of Lomechusa infection. Similar pseudogynes are also

produced in the Formica colonies infested with Atemeles and Xenodusa, but not in the Myrmica and Camponotus colonies in which the beetles hibernate, because they do not breed among their winter hosts and can not therefore interfere with the normal development of their brood.

Such being the effect on the colonies that harbor the Lomechusini, one naturally inquires why the habit of rearing the parasites has not long since led to the extinction of the Formicas. This question has been partially answered by Wasmann. He finds that the ants treat the Lomechusa larvæ like their own, even when they are ready to pupate. *F. sanguinea*, like many other ants, buries its full-grown larvæ in the soil in order that they may spin their cocoons and pupate within them. After pupation the cocoons are unearthed, cleaned and stacked up in the chambers of the nest. Now the full-grown Lomechusa larvæ also need to be buried in order to pupate, though they do not spin cocoons, but they must not be unearthed after pupation, like the ant brood, or they perish. The ants, however, are utterly ignorant of these different developmental requirements and therefore unearth as many of the Lomechusa pupæ as they can find. Thus death in the guise of what might be called a regulatory Nemesis overtakes all except the few pupæ that have been overlooked by the ants, but these few suffice to insure the survival of the species. More recently Wasmann has claimed that *sanguinea* takes a particular liking to certain pairs of beetles and eliminates the less attractive individuals from the colony. Of course, this would still further tend to reduce the incidence of parasitism and its baneful effects on the host.

The behavior of *sanguinea* and Lomechusa has seemed to Wasmann so unique and extraordinary that he has used it on every occasion as furnishing brilliant proofs of the absence of intelligence in ants, of the impotence of natural selection, of the possession by *sanguinea* of a singular, innate Lomechusa-fostering instinct, and therefore of a new type of selection, which he calls "amical selection," and, finally, even of the Divine Wisdom in maintaining the equilibrium in nature. Being a very accomplished Jesuit he has devoted many hundred pages and much scholastic casuistry to these "proofs." To the biologist who is under no compulsion to make his conclusions square with the philosophy of St. Thomas Aquinas, the behavior of *sanguinea* appears in a very different light, as a brilliant example of the perversion of appetites. Escherich has compared the infatuation of the Lomechusa-cherishing *sanguinea* with alcoholism in the human species. It might also be compared with a cat's infatuation with cat-nip, and the rearing of the Lomechusa larvæ by the ants would

seem to be due to the same kind of instinct perversion that we observe in the birds that rear cuckoos, the occasional cat that rears a puppy or the hen that adopts kittens. It would seem to be no more necessary to postulate a special Lomechusa-rearing instinct in *sanguinea* than a special ice-cream instinct in our children or a special Havana-cigar instinct in old bachelors.

That the behavior of *sanguinea* towards Lomechusa proves nothing in regard to intelligence, even when the word is used, as it is always used by Wasmann, in the scholastic sense, that is, as equivalent to reason, or ratiocination, has been shown by Hobhouse. After referring to Wasmann's conclusions, he says: "Difficult as it is to conceive the psychological conditions under which such contrasts are possible, we may still get some help from the analogy of human action. When comparative psychologists take occasional inconsistency as proving the utter absence of intelligence (in animals) they are using an argument which would equally disprove the existence of intelligence in man. After all, is an ant nourishing parasites that destroy its young guilty of a greater absurdity than, say, a mother promoting her daughter's happiness by selling her to a rich husband, or an inquisitor burning a heretic in the name of Christian charity, or an Emperor forbidding his troops to give quarter in the name of civilization? The mother really desires her daughter's happiness, but her conception of the means thereto is confused, and rendered self-contradictory by worldly ambitions. The inquisitor's conception of Christian charity is similarly corrupted by the subtle corporate egoism of a Church and the cruel pedantry of bad theology. Even the Emperor has some conception of civilization, but it is the civilization of militarism. In all cases there impinge on the avowed plan of action conflicting impulses of a kind not to stop the course of action, but to merge in it and distort it."

Hobhouse also comments trenchantly on Wasmann's conception of the maneuvers of the Divine Wisdom in maintaining the equilibrium of parasite and host, but I will pass over this matter, because it involves a consideration of the problem of evil and belongs to the philosopher and the theologian. The cases of social parasitism considered in the first part of this lecture and the behavior of *sanguinea* and Lomechusa suggest a few concluding remarks on a matter that is often overlooked. It is evident that a parasitic species is more seriously affected and at a much greater disadvantage than a host species, notwithstanding the suffering or death that may be inflicted on individual host colonies. Without exception, the hosts of all the known social parasites and Lomechusini are very common, prolific, widely distributed and therefore

very plastic or adaptable ant, and the instances of infection of these hosts are local or sporadic. This is even the case with *Formica fusca*, which occurs practically over the whole northern hemisphere and is infested by an extraordinary series of social parasites. It is enslaved by *F. sanguinea* and *Polyergus rufescens* and serves as the temporary host of many parasitic Formicas, including *rufa*, *truncicola*, *dakotensis*, *exsecta*, *exsectoides*, etc. We may conclude, therefore, that *fusca* and the other hosts of parasitic ants and Lomechusini have developed more or less resistance or even a certain local immunity to the inroads of the parasites, and that the parasites even when successful exploit merely that margin of super-abundant vitality and fecundity which every healthy organic species possesses. Hence the occasional destruction of colonies by the parasites does not seriously endanger the life of the host species. If this were the case the hosts would be scarce or would have disappeared long ago. The same considerations probably apply to the human species, for it would seem that only man's world-wide distribution, great fecundity and wonderful adaptability have enabled him to survive all the terrible exploitations to which he has been subjected.

THE THEORY OF RELATIVITY AND ITS INFLUENCE ON SCIENTIFIC THOUGHT[1]

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IN the days before Copernicus the earth was, so it seemed, an immovable foundation on which the whole structure of the heavens was reared. Man, favorably situated at the hub of the universe, might well expect that to him the scheme of nature would unfold itself in its simplest aspect. But the behavior of the heavenly bodies was not at all simple; and the planets literally looped the loop in fantastic curves called epicycles. The cosmogonist had to fill the skies with spheres revolving upon spheres to bear the planets in their appointed orbits; and wheels were added to wheels until the music of the spheres seemed well-nigh drowned in a discord of whirling machinery. Then came one of the great revolutions of scientific thought, which swept aside the Ptolemaic system of spheres and epicycles, and revealed the simple plan of the solar system which has endured to this day.

The revolution consisted in changing the viewpoint from which the phenomena were regarded. As presented to the earth the track of a planet is an elaborate epicycle; but Copernicus bade us transfer ourselves to the sun and look again. Instead of a path with loops and nodes, the orbit is now seen to be one of the most elementary curves—an ellipse. We have to realize that the little planet on which we stand is of no great account in the general scheme of nature; to unravel that scheme we must first disembarrass nature of the distortions arising from the local point of view from which we observe it. The sun, not the earth, is the real center of the scheme of things—at least of those things in which astronomers at that time had interested themselves—and by transferring our viewpoint to the sun the simplicity of the planetary system becomes apparent. The need for a cumbrous machinery of spheres and wheels has disappeared.

Every one now admits that the Ptolemaic system, which regarded the earth as the center of all things, belongs to the dark

[1] The Romanes Lecture for 1922, delivered in the Sheldonian Theatre, Oxford, and printed by the Clarendon Press.

ages. But to our dismay we have discovered that the same *geocentric* outlook still permeates modern physics through and through, unsuspected until recently. It has been left to Einstein to carry forward the revolution begun by Copernicus—to free our conception of nature from the terrestrial bias imported into it by the limitations of our earthbound experience. To achieve a more neutral point of view we have to imagine a visit to some other heavenly body. That is a theme which has attracted the popular novelist, and we often smile at his mistakes when sooner or later he forgets where he is supposed to be and endows his voyagers with some purely terrestrial appanage impossible on the star they are visiting. But scientific men, who have not the novelist's license, have made the same blunder. When, following Copernicus, they station themselves on the sun, they do not realize that they must leave behind a certain purely terrestrial appanage, namely, *the frame of space and time* in which men on this earth are accustomed to locate the events that happen. It is true that the observer on the sun will still locate his experiences in a frame of space and time, if he uses the same faculties of perception and the same methods of scientific measurement as on the earth; but the solar frame of space and time is not precisely the same as the terrestrial frame, as we shall presently see.

I think you will readily understand what is meant by a *frame* of space and time. It is the system of location to which we appeal when we state, for example, that one event is 100 miles distant from and 10 hours later than another. The terms space and time have not only a vague descriptive reference to a boundless void and an ever-rolling stream, but denote an exact quantitative system of reckoning distances and time-intervals. Einstein's first great discovery was that there are many such systems of reckoning—many possible frames of space and time—exactly on all fours with one another. No one of these can be distinguished as more fundamental than the rest; no one frame rather than another can be identified as the scaffolding used in the construction of the world. And yet one of them does present itself to us as being the actual space and time of our experience; and we recoil from the other equivalent frames which seem to us artificial systems in which distance and duration are mixed up in an extraordinary way. What is the cause of this invidious selection? It is not determined by anything distinctive in the frame; it is determined by something distinctive in us—by the fact that our existence is bound to a particular planet and our motion is the motion of that planet. *Nature* offers an infinite choice of frames; *we* select the one in which we and our petty terrestrial concerns take the most distinguished position. Our mis-

chievous, geocentric outlook has cropped out again unsuspected, persuading us to insist on this terrestrial space-time frame which in the general scheme of nature is in no way superior to other frames.

The more closely we examine the processes by which events are assigned to their positions in space and time, the more clearly do we see that our local circumstances play a considerable part in it. We have no more right to expect that the space-time frame on the sun will be identical with our frame on the earth than to expect that the force of gravity will be the same there as here. If there were no experimental evidence in support of Einstein's theory, it would nevertheless have made a notable advance by exposing a fallacy underlying the older mode of thought—the fallacy of attributing unquestioningly a more than local significance to our terrestrial reckoning of space and time. But there is abundant experimental evidence for detecting and determining the difference between the frames of differently circumstanced observers. Much of the evidence is too technical to be discussed here, and I can only refer to the Michelson-Morley experiment. I fear that some of you must be getting rather tired of the Michelson-Morley experiment; but those who go to a performance of Hamlet have to put up with the Prince of Denmark.

This famous experiment is a simple test whether light travels at the same speed in two different directions. For this purpose an apparatus is constructed with two equal arms at right angles, providing two equal tracks for the light. A beam of light is divided into two parts so that one part travels along one arm and back, and the other along the other arm and back. The two rays then reunite, and by delicate interference tests it is possible to tell if one has been delayed more than the other; a delay of less than a thousand-billionth of a second could be detected. The experiment is simply a race between two light-rays with equal tracks, but pointing in different directions; the result turns out to be a dead-heat. At first sight this is just what would be expected; and one almost wonders why it should have been thought worth while to try the experiment. But Michelson, like a good Copernican, had stationed himself on the sun to watch the race; accordingly he realized that the apparatus was being borne along by the earth's orbital motion with a speed of 20 miles a second. Consequently the light does not travel exactly the double length of the arm; starting at one end it has to go to the turning-mark at the other end which has moved on a little in the meantime; then it returns to the place which the starting-mark has travelled to whilst the race is in progress. That does not add up to exactly the double length of the

arm. Making the calculations we easily find that, although the two arms are equal, the two light-journeys are unequal; the competitor whose track lies in the line of the earth's motion has the longer journey, and is at a disadvantage. And yet according to the experiment he does not suffer the expected delay. From our standpoint on the sun, the experiment seems to have gone wrong; Copernicus has met with a rebuff, and Ptolemy is triumphant.

But that is because we have not admitted the full consequences of transferring our standpoint to the sun. We have all the while been keeping one foot on earth. Of course, the whole experiment turns on the two arms having been first adjusted to perfect equality. This could only be ascertained by experiment; and the test applied was to rotate the apparatus through a right angle, so that if, for example, the journey in the line of the earth's motion had had the advantage of the shorter arm on one occasion, the transverse journey would have had it on the repetition. That is a perfectly satisfactory test for a terrestrial observer; to turn a rod from one direction to another is the simple and direct way of marking out equal lengths. But the test is not satisfactory to an observer on the sun; he would not think of attempting to partition equal lengths of space by means of rods travelling at 20 miles a second. His frame of space—the space not only of refined measurement, but also of the cruder measurements made with the sense-organs of his body which determine his perception of space—is partitioned by appliances at rest relatively to him, *e. g.*, his own eyes and limbs. Lengths of objects carried on the earth must be judged by him according to the room they occupy in his own frame. In the space of the terrestrial observer the two arms of the apparatus were adjusted to equal length; but in the re-partitioned space of the solar observer they may quite well occupy unequal lengths, and when we take the viewpoint of an observer on the sun we must not overlook this inequality. This inequality is not so much a hypothesis proposed to account for Michelson's result as a direct deduction from it. The two light-journeys were found to occupy equal times; this clearly shows that the arm in the less favored direction is shorter than the other so as to counterbalance the handicap to which I have referred.[2]

When the apparatus is turned through a right angle, the experiment still gives the same result. It does not matter which of

[2] The only alternative is that (relatively to a solar observer) the velocity of light differs in different directions, at least in the region where the experiment is conducted. This would presumably be due to some influence of the moving earth on the propagation of light (convection of the ether). This explanation was at one time favored, but it could not be reconciled with the observed phenomena of the aberration of light.

the two arms we place in the line of the earth's motion; that arm must be shorter than the other. In other words each arm must automatically contract when it is turned from the transverse to the longitudinal position with respect to its line of motion. This is the famous FitzGerald contraction of a moving rod. It is of the same amount whatever the material of the rod, and depends only on the speed of its motion. For the earth's orbital motion the contraction amounts to one part in 200 million; in fact the earth's diameter in the direction of its motion is always shortened by 2½ inches, the transverse diameter being unaffected.

This contraction of a moving material object was first revealed to us by the Michelson-Morley experiment; but it is not at all disagreeable to theoretical anticipations. We have to remember that a rod consists of a large number of molecules kept in position by their mutual forces. The chief force is the force of cohesion, and there is little doubt that this is of electrical nature. But when the rod is set in motion, the electrical forces inside it must change. For example, each electric charge when put in motion becomes *an electric current;* and the currents will exert magnetic attractions on each other which did not occur in the system at rest. Under the new system of forces the molecules will have to find new positions of equilibrium; they become differently spaced; and it is therefore not surprising that the form of the rod changes. Without going beyond the classical laws of Maxwell we can anticipate theoretically what will be the new equilibrium state of the rod, and it turns out to be contracted to the exact amount required by the Michelson-Morley result.

The contraction of the moving rod ought not to surprise us; it would be much more surprising if the rod were to maintain the same form in spite of the alteration of the electrical forces which determine the spacing of the molecules. But the remarkable thing is that the contraction is only apparent according to the outlook of the solar observer; and we on the earth, who travel with the rod, can not appreciate it. The fact that the contraction happens to be very small is irrelevant. For convenience suppose that the earth's velocity is 8,000 times faster, so that the contraction amounts to something like a half the original length. We should still fail to notice it in everyday life. Let us say that the direction of the earth's motion is vertically upwards. I turn my arm from horizontal to vertical and it contracts to half its length. No, you can not convince me I am wrong; I am not afraid of a yard-measure. Bring one and measure my arm; first horizontally, the result is 30 inches; now vertically, the result is 30—half-inches! Because you must remember that you have turned the scale into

the line of the earth's motion so that each inch-division contracts to half an inch. "But we can see that your arm does not contract. Are we not to trust our eyes?" Certainly *not,* unless you first correct your visual impressions for the contraction of the retina in the vertical direction, and for the effect of our rapid motion on the apparent direction of propagation of the waves of light. You will find, when you calculate these corrections, that they just conceal the contraction. "But if the contraction takes place, ought one not to feel it happening to the arm?" Not necessarily; I am an observer of the earth, and my feelings like other sense-impressions belong to the geocentric outlook on nature, which Copernicus has persuaded us to abandon.

Take a pair of compasses and twiddle them on a sheet of paper. Is the resulting curve a circle or an ellipse? Copernicus from his standpoint on the sun declares that owing to the FitzGerald contraction the two points drew nearer together when turned in the direction of the earth's orbital motion; hence the curve is flattened into an ellipse. But here I think Ptolemy has a right to be heard; he points out that from the beginning of geometry circles have always been drawn with compasses in this way, and that when the word "'circle" is mentioned every intelligent person understands that this is the curve meant. The same pencil line is in fact a circle in the space of the terrestrial observer and an ellipse in the space of a solar observer. It is at the same time a moving ellipse and a stationary circle. I think that illustrates as well as possible what we mean by *the relativity of space.*

It is sometimes complained that Einstein's conclusion that the frame of space and time is different for observers with different motions tends to make a mystery of a phenomenon which is not after all intrinsically strange. We have seen that it depends on a contraction of moving objects which turns out to be quite in accordance with Maxwell's classical theory. But even if we have succeeded in explaining it to ourselves intelligibly, that does not make the statement any the less true! A new result may often be expressed in various ways; one mode of statement may sound less mysterious; but another mode may show more clearly what will be the consequences in amending and extending our knowledge. It is for the latter reason that we emphasize the relativity of space—that lengths and distances differ according to the observer implied. Distance and duration are the most fundamental terms in physics; velocity, acceleration, force, energy, and so on, all depend on them; and we can scarcely make any statement in physics without direct or indirect reference to them. Surely then we can best indicate the revolutionary consequences of what we have learned by the

statement that distance and duration, and all the physical quantities derived from them, do not as hitherto supposed refer to anything absolute in the external world, but are relative quantities which alter when we pass from one observer to another with different motion. The consequence in physics of the discovery that a yard is not an absolute chunk of space, and that what is a yard for one observer may be eighteen inches for another observer, may be compared with the consequences in economics of the discovery that a pound sterling is not an absolute quantity of wealth, and in certain circumstances may "really" be seven and sixpence. The theorist may complain that this last statement tends to make a mystery of phenomena of currency which have really an intelligible explanation; but it is a statement which commends itself to the man who has an eye to the practical applications of currency.

Ptolemy on the earth and Copernicus on the sun are both contemplating the same external universe. But their experiences are different, and it is in the process of experiencing events that they become fitted into the frame of space and time—the frame being different according to the local circumstances of the observer who is experiencing them. That, I take it, is Kant's doctrine, "Space and time are forms of experience." The frame then is not in the world; it is supplied by the observer and depends on him. And those relations of simplicity, which we seek when we try to obtain a comprehension of how the universe functions, must lie in the events themselves before they have been arbitrarily fitted into the frame. The most we can hope for from any frame is that it will not have distorted the simplicity which was originally present; while an ill-chosen frame may play havoc with the natural simplicity of things. We have seen that the simplicity of planetary motions was obscured in Ptolemy's frame, and became apparent in Copernicus's frame. But for ordinary terrestrial phenomena the position is reversed and Ptolemy's frame allows their natural simplicity to become apparent. In Copernicus's frame the most simple phenomena are brought about by highly complicated processes which mutually cancel one another. Ordinary objects contract and expand as they are moved about, and the changes are concealed by an elaborate conspiracy in which all the quantities of nature—electrical, optical, mechanical, gravitational—have joined. In Copernicus's frame we have a great complication of description which has no counterpart in anything occurring in the external world; because the terms of our description refer to the irrelevant process of fitting into the selected frame of space and time. This elaborate Copernican scheme rather reminds one of the schemes of the White Knight—

> But I was thinking of a plan
> To dye one's whiskers green,
> And always use so large a fan
> That they could not be seen.

We do not deny the subtlety and the remarkable efficiency of the plan; but we may be allowed to question whether it is the simplest interpretation of the drab monotony of the face of nature presented to us. The simple fact is that a terrestrial or Ptolemaic frame fits naturally the terrestrial phenomena, and a solar or Copernican frame fits the phenomena of the solar system; but we can not make one frame serve for both without introducing irrelevant complications.

We go beyond Copernicus nowadays, and are not content with a visit to the sun. Why choose the sun rather than some other star in order to obtain an undistorted view of things? The astronomer now places himself so as to travel with the center of gravity of the stellar universe, and is not even then quite satisfied. The physicist dreams of a land of Weissnichtwo, which shall be truly at rest in the ether. We realize the distortion imported into the world of nature by the parochial standpoint from which we observe it, and we try to place ourselves so as to eliminate this distortion—so as to observe that which actually *is*. But it is a vain pursuit. Wherever we pitch our camera, the photograph is necessarily a two-dimensional picture distorted according to the laws of perspective; it is never a true semblance of the building itself.

We must try another plan. I do not think we can ever eliminate altogether the human element in our conception of nature; but we can eliminate a particular human element, namely, this framework of space and time. If our thought must be anthropocentric, it need not be geocentric. Nor are we permanently better off if we merely substitute the space-time frame of some other star or standard of motion. We must leave the frame entirely indeterminate. When we do that, we find that the world common to all observers—in which each observer traces a different space-time frame according to his own outlook—is a world of four dimensions. When we look at any object, say a chair, the impression on our eyes is a two-dimensional picture depending on the position from which we are looking; but we have no difficulty in conceiving of the chair as a solid object, not to be identified with any one of our two-dimensional pictures of it, but giving rise to them all as the position of the observer is varied. We must now realize that this solid chair in three dimensions is itself only an appearance, which changes according to the motion of the observer, and that there is a super-object in four dimensions, not to be identified with the

three-dimensional chair in Ptolemy's scheme, or the same chair in Copernicus's scheme, but giving rise to both these appearances. The synthesis of a three-dimensional chair from a number of flat pictures is easy to us because we are accustomed to assume different positions in rapid succession; indeed our two eyes give us slightly different points of view simultaneously. By sheer necessity our brains have been forced to construct the conception of the solid chair to combine these changing appearances. But we do not vary our motion to any appreciable extent and our brains have not hitherto been called upon to combine the appearances for different motions; thus the effort which we now ask the brain to make is a novel one. That explains why the result seems to transcend our ordinary mode of thought.

The discovery, or one should rather say the rediscovery, of the world of four dimensions is due to Minkowski. Einstein had worked out fully the relations between the frames of space and time for observers with different motions. To the genius of Minkowski we owe the realization that these frames are merely systems of partitions arbitrarily drawn across a four-dimensional world which is common to all observers.

There is a strange delusion that the fourth dimension must be something wholly beyond the conception of the ordinary man, and that only the mathematician can be initiated into its mysteries. It is true that the mathematician has the advantage of understanding the technical machinery for solving the problems which may arise in studying the world of four dimensions; but as regards the conception of the four dimensions of the world his point of view is the same as that of anybody else. Is it supposed that by intense thought he throws himself into some state of trance in which he perceives some hitherto unsuspected direction stretching away at right angles to length, breadth and thickness? That would not be much use. The world of four dimensions, of which we are now speaking, is perfectly familiar to everybody. It is obvious to every one—even to the mathematician—that the world of solid and permanent *objects* has three dimensions and no more; that objects are arranged in a threefold order, which for any particular individual may be analyzed into right-and-left, backwards-and-forwards, up-and-down. But it is no less obvious to every one that the world of *events* is of four dimensions; that events are arranged in a fourfold order, which in the experience of any particular individual will be analyzed into right-and-left, backwards-and-forwards, up-and-down, *sooner-and-later*. The subject of our study is external nature, which is a world of events, common to all observers, but represented by them differently in their parochial frames of space

and time; it is obvious to the most commonplace experience that this absolute world contains a fourfold order.[3]

The news that the events around us form a world of four dimensions is as stale as the news that Queen Anne is dead. The reason why the relativist resurrects this ancient truism is because it is only in this undissected combination of four dimensions that the experiences of all observers meet. In our own experience one dimension is sharply separated from the other three and is distinguished as time; but our experience is solely terrestrial, and if we insist on building the scheme of nature on purely terrestrial experience we are limiting ourselves to the medieval geocentric system of the world.

We have been accustomed to regard the enduring world as composed of a continuous succession of instantaneous states, as though the world of events were *stratified*. Each event is supposed to lie in a definite instant or stratum, and the orderly succession of these strata makes up the whole of reality. The instant "now" represents one such stratum running throughout the universe. Indeed, we are accustomed to extend it beyond the universe, and we even use the word "now" with reference to the existence of those who have passed away from the material world. The investigations of the relativity theory show incontrovertibly that this supposed stratification is an illusion; there is not the slightest evidence for such a view of world structure. The instantaneous state, which we have hitherto taken to be a natural stratum in the four-dimensional world of events is merely an arbitrary partition created by ourselves to correspond with our geocentric outlook. We can take a differently inclined partition,[4] that is to say, a section which includes on the one side of us events which happened a little while

[3] The relativity theory does not suggest that there is such a thing in nature as a four-dimensional *space*. The whole object of the recognition of the four-dimensional world is to eliminate the harassing frame of space.

[4] The inclination must not exceed a certain limit. This limiting angle may be regarded as a fundamental constant of the world-structure, and owing to its fundamental character it appears in many kinds of phenomena; for example, it determines the velocity of propagation of light. The instant on the sun which is simultaneous with a given instant on the earth is indeterminate (varying according to the space and time frame employed) but only within a range of 16 minutes. Any event on the sun happening before this 16 minutes is *absolutely* in the past, all observers agreeing on this point; in fact it would be possible for us to have already received a wireless message announcing its occurrence. Events after the 16 minutes are in the *absolute* future. The neutral zone which is (absolutely) neither past nor future becomes proportionately wider as the distance increases; at the nearest fixed star it extends to 8 years, and at the most distant stars yet known it reaches 400,000 years.

ago and on the other side of us events which have not yet happened; such a farcical combination is in every way equivalent to our so-called instantaneous state, and indeed it *is* an instantaneous state according to the outlook of some non-terrestrial observer with suitably assigned motion.

It is so contrary to our natural prejudices to recognize that the world-wide instant *now* is created by ourselves and has no existence apart from our geocentric outlook, that I will spend a few moments trying to show its artificiality. When I say that I am conscious of an instant *now*, I am only conscious of it in so far as it is *here*—inside me. What then has led me to imagine that there exists a continuation of it outside me? It is because I look out on the world and see various events happening "now," so that I jump to the conclusion that this instant of which I am conscious has to be extended to include them. But that idea is another inheritance from the dark ages, overthrown by Römer in 1675. It is not the events themselves but the sense-impressions to which they give rise which are happening in the instant *now*. So my justification for placing the events outside me in the instants of which I am conscious has entirely disappeared. Unfortunately, however, the crude outlook was not abolished, but patched up; it was found that the immediate difficulties could be met by locating the external events not in the instant of our visual perception of them but in an instant which we had experienced a little time back—allowing, as we say, for the time of propagation of light. Thus our instants were still made to extend through space; but they were carried like partitions among the events by an artificial process of computation, and no longer by immediate intuition. The relativity theory recognizes these *world-wide instants* for what they are—artificial partitions constructed for purposes of calculation. I may add that it in no way tampers with the *local instants* which form the stream of our consciousness; it fully recognizes that the chain of events in such a time-succession is a series of an entirely distinctive character from the succession of points along a line in space. Those who suspect that Einstein's theory is playing unjustifiable tricks with time should realize that it leaves entirely untouched that time-succession of which we have intuitive knowledge, and confines itself to overhauling the artificial scheme of time which Römer first introduced into physics.

The study of the four-dimensional world of events gives us a new insight into the processes of nature because it removes the irrelevant stratification in a particular direction—the instantaneous states—which we have so unnecessarily introduced in our customary outlook. When this stratification is ignored we are en-

abled to see the processes in their simplest aspect, though not, of course, in their most familiar aspect. We must distinguish between simplicity and familiarity; a pig may be most familiar to us in the form of rashers, but the *unstratified* pig is a simpler object of study to the biologist who wishes to understand how the animal functions.

I will conclude this part of the argument with an experimental application which illustrates the power of Einstein's method. Much study has of late been given to electrons moving with very high speeds; for example, the β particles shot off from radioactive substances are negative electrons which sometimes attain speeds of 100,000 miles a second. It is found by experiment that the rapid motion produces an increase of mass of these particles. I want to show that the theory of relativity gives a very simple explanation of just how this increase of mass occurs. But I must first remark that an explanation had been previously given which had generally been accepted as satisfactory. The phenomenon was actually predicted by J. J. Thomson before relativity was thought of; because, assuming that the mass of a β particle is of electrical origin, an application of Maxwell's equations shows that it ought to increase with velocity. But the precise law of increase can not be predicted on this basis, since various plausible assumptions lead to slightly different results. Moreover, Maxwell's equations are after all only empirical laws, with a mystery of their own; it was a notable advance to connect the change of mass at high speeds with other phenomena whose strangeness has disappeared by long familiarity, but there is still scope for a more far-reaching explanation. Einstein takes us straight to the root of the mystery, and he clears up one point which was misleading, if not actually wrong, in the older explanation. The change of mass does not in any way depend on whether the mass is of electrical origin or not; it arises simply from the fact that mass is a *relative* quantity, depending by its definition on the relative quantities length and time. Let us look at the β particle from its own point of view; it is just an ordinary electron in no way different from any other. "But it is travelling unusually rapidly?" "That," says the electron, "is a matter of opinion. So far as I am aware I am at rest, if the word 'rest' has any meaning. In fact I was just contemplating with amazement *your* extraordinary speed of 100,000 miles a second with which you are shooting past me." Of course our motion is of no particular concern to the electron, and it will not modify its constitution on our account; so it keeps its mass, radius, electric field, etc., equal to the standard constants applying to electrons in general. These terms are relative, and refer therefore to some particular frame

of space and time—clearly the frame appropriate to an electron in self-contemplation, *viz.*, the one with respect to which it is at rest. But this frame is not the usual geocentric frame to which *we* refer quantities such as length, time, and mass; there is a difference of 100,000 miles a second between our station of observation and that of the β particle in self-contemplation. It is a mere matter of geometry to discover what the β particles' lengths and times become when referred to the partitions which we have drawn across the world. But when we calculate the consequential change of mass resulting from the changes of length and time, we find that it should be increased in precisely the proportion indicated by the most refined experiments.

The point is that every electron, at rest or in motion, is a perfectly constant structure; but we distort it by fitting it into the space-time frame appropriate to our own motion with which the electron has no concern. The greater our motion with respect to the electron, the greater will be the distortion. The distortion is not produced by any physical agency at work in the electron; it is a purely subjective distortion depending on our transformation of the reference frame of space and time. This distortion involves a change in our physical description of the electron in terms of mass, shape, size; and in particular the change of mass agrees precisely with that found experimentally.

You see that it is not altogether idle discussing the natural space-time frames for observers moving with huge velocities. We know of no animate observers with these speeds; but we do know of inanimate material objects. Their common resemblance is obscured when we refer them indiscriminately to our irrelevant geocentric frame; we think they have altered their properties, varied in mass, and so on; but the resemblance is restored when we refer each individual to the frame appropriate to it, and so describe them all in comparable terms.

Our measurements of distance in space are found to be subject to certain laws—the laws of geometry. But it has now become impossible to regard the subject of space-geometry as complete in itself. Consider a triangle formed by three points (or events) in the four-dimensional world; if we happen to have drawn our instantaneous strata so that the three points lie in one stratum, then the triangle is a space-triangle and its properties fall within the scope of our classical geometry. But another observer will draw his strata in a different direction, and for him the triangle would be partly in space and partly in time, so that it would not be a fit subject for space-geometry. The subject of geometry is in a desperate condition, because Copernicus and Ptolemy not merely dis-

agree as to the geometry of a configuration; they even disagree as to whether a given configuration is one to which space-geometry is applicable. It is clear that to save it we must extend our geometry so as to include time as well as space. Let me give an illustration of this extension. The terrestrial observer can have a space-triangle (formed by three points or events at the same instant) whose sides he can measure with scales; he can also have a "time-triangle," formed by three events on different dates, whose sides he must measure with *clocks*.[5] You all know the law of the space-triangle—that if you measure with a scale from A to B and from B to C the sum of the readings is always *greater* than the measure from A to C. It is not so well known that there is a precisely analogous law for the time-triangle—that if you measure with a clock from A to B and from B to C the sum of the readings is always *less* than the reading of a clock measuring directly from A to C. In the space-triangle any two sides are together *greater* than the third side; in the time-triangle two sides are together *less* than the third side.[6] Both these laws must be combined in our general geometry of four dimensions, so that it will not be quite so simple a geometry as that to which we are accustomed.[7]

But the point to which I would especially direct attention is this. Evidently the proposition which I have given you about time-triangles can not be dissociated from the corresponding proposition about space-triangles. When we give up the medieval geocentric standpoint, we must recognize that they belong to one geometry, of which our ordinary space-geometry is only a part or projection. But if you examine the proposition about time-triangles, you will see that it is a statement about the behavior of clocks when they move about, a subject which obviously comes under the heading of mechanics. When we deal with the four-dimensional world we can no longer distinguish between geometry and mechanics. They become the same subject. When we have completely mastered the geometry of the world of events, we shall have inevitably learned

[5] The three events must not be at the same place since that would give a time-*line* not a triangle. The clock must move so that the two events whose time-distance is to be determined both happen where it is, just as the scale must be directed so that the two points fall on it. You are not allowed to "bend" the clock, *i. e.*, apply force so as to make it move with other than uniform velocity, any more than you are allowed to bend the scale by applying force.

[6] Of course, it is not true that *any* two sides are less than the third side. A clock, unlike a scale, can only measure in one direction, *viz.*, from past to future, so that the sides $AB + BC$ and AC can be chosen in only one way.

[7] This involves only a comparatively trifling generalisation of Euclidean geometry, not to be confused with the "non-Euclidean" geometry introduced later in the lecture.

the mechanics of it. That is why Einstein, studying the geometry of the world and discovering that it was strictly non-Euclidean, found that he was at the same time studying the mechanical force of gravitation. And when he had made up his mind which of the possible varieties of non-Euclidean geometry was obeyed, and so settled the laws of the new geometry, the same decision settled the law of gravitation—a law approximating to, but not identical with, the law which Newton had given.

Here a wide vista opens before us. We see that two great divisions of mathematical physics, *viz.*, geometry and mechanics, have met in the four-dimensional world. It is not merely that mechanical problems can be treated by formulæ originally belonging to pure geometry; that device has long been in use. Experimental geometry and mechanics actually relate to the same subject-matter: and the young student who discovers experimental laws with ruler and compasses and cardboard figures, and later goes on to pendulums and spring-balances, is developing a single subject which can not be divided any more than the subject of magnetism can be divided from electricity.

It is through this unification of geometry and mechanics that I should like to approach the problem of gravitation, showing that a field of force is a manifestation of the geometry of space and time. But I fear that that would be too technical; so we will approach it from a different angle.

We have shown that the contemplation of the world from the standpoint of a single observer is liable to distort its simplicity, and we have tried to obtain a juster idea by taking into account and combining other points of view. The more standpoints the better. Let us now consider another point of view, which we have not previously thought about—the point of view of an observer who has tumbled out of an aeroplane and is falling headlong. In many respects his is an ideal situation—temporarily. Unfortunately on *terra firma* we are continually subjected to a very disturbing influence; we undergo a terrific bombardment by the molecules of the ground, which are hammering on the soles of our boots with a total force of some ten stone weight pressing us upwards. Now our bodies are the scientific appliances which we use to make our common observations of the world. I am sure that no physicist would permit any one to enter his laboratory and hammer on his clocks and galvanometers while he was observing with them; at any rate he would think it necessary to apply some corrections for the effect of the disturbance. Let us then allow ourselves to fall freely *in vacuo;* then we shall be free from this disturbing bombardment and able to take a much more natural view of what is going on around us.

While falling, we perform the experiment of letting go an apple held in the hand. The apple is now free, but it can not fall any more than it was falling already; consequently it remains poised in contact with our hand. In our new outlook—in our new frame of space and time—an apple does not drop. There is no mysterious force accelerating it. And remember that this new frame of space and time is the natural frame of a free observer; whereas the old frame, in which the mysterious accelerating force occurred, was the frame of a very much disturbed observer. It is true that when we look down at the earth we see trees and houses rushing up to meet us; but there is no mystery about that. There is an obvious cause for it; plainly they are being propelled upwards from below by that molecular bombardment which I have mentioned. You see that the apple's view of things is simpler than Newton's. Newton had to invent a mysterious force dragging the apple down; the apple observes only a familiar physical agency propelling Newton up.

It is not my purpose to emphasize unduly the superiority of the apple's view over Newton's, but rather to regard both on an equal footing. I have perhaps been a little unfair to Newton. His position on the surface of the earth was unfortunate, but he would have been perfectly content to be at the center of the earth, where he could have remained without support, *i. e.*, without disturbance by molecular bombardment. From there he would still have observed the well-known acceleration of the apple; and the apple would have observed a corresponding acceleration of Newton without any molecular bombardment causing it. From either point of view there is a mysterious agent at work. How shall we picture to ourselves this agent? Shall we picture it as a force—a tug of some kind? But if so, to which of them is the tug applied? If we take the standpoint of Newton the tug is applied to the apple, if the standpoint of the apple the tug is applied to Newton; so that in our synthesis of all standpoints we can not decide which is being tugged, and the picture of gravitation as a tugging agent becomes impossible. Einstein replaces it by a different picture, which we shall perhaps better understand if we compare it with a very similar revolution of scientific thought which occurred long ago.

The ancients believed that the earth was flat. The small portion of its surface with which they were chiefly concerned could be represented without serious distortion on a flat map. As more distant countries were added, it would be natural to think that they also could be included in the flat map. You have all seen such maps of the world, *e. g.*, Mercator's projection, and you will remember how Greenland appears enormously exaggerated in size.

Now those who adhered to the flat-earth theory must hold that the flat map gives the *true* size of Greenland. How then would they explain that travellers in that country reported that the distances were much shorter? They would, I suppose, invent a theory that a demon resided in that country who helped travellers on their way, making the journeys appear much shorter than they "really" were. No doubt the scientists would preserve their self-respect by using some Græco-Latin polysyllable instead of the word "demon," but that must not disguise from us the fact that they were appealing to a *deus ex machina*. The name demon is rather suitable, however, because he has the impish characteristic that we can not pin him down to any particular locality. We might equally well start our flat map with its center in Greenland; then it would be found that journeys there were quite normal, and that the activities of the demon were disturbing travellers in Europe. We now recognize that the true explanation is that the earth's surface is curved; and the demoniacal complications appeared because we were forcing the earth's surface into an inappropriate flat frame which distorts the simplicity of things.

What has happened in the case of the earth has happened also in the case of the world, and a similar revolution of thought is needed. An observer, say at the center of the earth, finds that there is a frame of space and time—a flat or Euclidean frame—in which he can locate things happening in his neighborhood without distorting their natural simplicity. There is no gravitation, no tendency of bodies to fall, so long as the observer confines his observations to his immediate neighborhood. He extends this frame of space and time to greater distances, and ultimately to the earth's surface where he encounters the phenomenon of falling apples. This new phenomenon must be accounted for, so he invents a *deus ex machina* which he calls gravitation to whose activities the disturbance is attributed. But we have seen that we may just as well start with the falling apple. It has a flat frame of space and time into which phenomena in its neighborhood fit without distortion; and from its point of view bodies near it do not undergo any acceleration. But when it extends this frame farther afield, the simplicity is lost; and it too has to postulate the demon force of gravitation existing in distant parts, and for example causing undisturbed objects at the center of the earth to fall towards it. As we change from one observer to another—from one flat space-time frame to another—so we have to change the region of activity of this demon. Is not the solution now apparent? The demon is simply the complication which arises when we force the world into a flat Euclidean space-time frame into which it does not fit without

distortion. It does not fit the frame, because *it is not a Euclidean or flat world.* Admit a curvature of the world and the mysterious disturbance disappears. Einstein has exorcised the demon.

Einstein, recognizing that in the phenomena of gravitation he was not dealing with a "tug" but with a curvature of the world, had to reconsider the law of gravitation. He could not make any possible law of curvature correspond exactly with the previously assumed law of tugging. Thus he was led to propound a new law of gravitation—a law which in most practical cases differs very little from that of Newton, although it has an essentially different foundation. I need not here dwell on the very remarkable way in which Einstein's emendation of the law of gravitation has been confirmed both by the anomalous secular change in the orbit of the planet Mercury, and by the observed displacement of the stars near the sun during the total eclipse of 1919. I might, however, remind you that in the latter observation the point at issue between Newton's and Einstein's theory was not the *existence* of a deflexion of light-rays passing near the sun but the amount of the deflexion, Einstein predicting twice the deflexion possible on the Newtonian theory. The larger deflexion was quantitatively confirmed by the eclipse observations. Einstein's main achievement is a new law, not a new explanation, of gravitation. He attributes the gravitation of massive bodies to a curvature of the world in the region surrounding them and so throws a flood of light on the whole problem; but he is not primarily concerned to explain how material bodies produce (or are associated with) this curvature of the world around them, nor how this curvature is made subject to a law. Although it would be an entire misunderstanding of Einstein's attitude in propounding the general relativity theory to regard it as a search for an explanation of gravitation, nevertheless I think that the further following up of his ideas has led to a genuine explanation as complete as could be desired. But I am not going to give you the explanation in this lecture; sometimes an explanation requires a great deal of explaining.[8]

[8] The following brief outline will give a hint of the nature of the explanation. Einstein's law of gravitation is usually expressed as a set of ten very lengthy differential equations; these equations are exactly equivalent to the geometrical statement that "the radius of spherical curvature of any 3-dimensional section of the 4-dimensional world is a universal constant length, the same for all points of the world and for all directions of the section." The law therefore implies that the world has a certain type of homogeneity and isotropy (not, however, the *complete* homogeneity and isotropy of a sphere). To explain the law of gravitation and the phenomena governed by it, we have to explain how this isotropy and homogeneity is secured. Our explanation is that the homogeneity and isotropy is not initially in the external world, but *in the measurements which we make of it.* It is introduced in all

I think that we can without mathematics form a general idea of why Einstein found it necessary to amend Newton's law of gravitation. Let us return to the illustration of the pig, and imagine that we wish to discover the law governing the distribution of fat and lean in the animal. From the breakfast-table standpoint a plausible type of law would be that half of each rasher is fat and the other half lean; and if this turned out to be confirmed very approximately by observation we might well imagine that we had discovered the exact law of porcine structure. But the case is altered if we give up the breakfast-table standpoint and contemplate the animal in a more general way, remembering that he has not been designed with any particular reference to the series of rashers into which our grocer has chosen to slice him. We must now look for a different type of law altogether. Two possibilities may arise. We may find that our proposed law, although expressed in breakfast-table parlance, is nevertheless equivalent to a possible biological law; it may be immediately capable of translation into a more general statement which makes no reference to a particular stratification. But on the other hand, it may happen that the suggested law can not be freed from this reference to a particular system of slicing. In that case we can only regard it as approximate, perhaps holding fairly well for the slices of which we have most experience but becoming less and less accurate in the more tortuous parts of the animal. Both of these cases are illustrated in Einstein's modifications of classical theory. Newton's law of gravitation explicitly refers to a space-time frame and therefore to a world stratified into instantaneous states. It proves to be impossible to free it from this reference to a particular stratification without modifying it. In fact if the crucial astronomical observations had shown that Newton's law and not Einstein's was the exact law of gravitation, this would have been evidence of a real stratification of the structure of the world—a stratification revealed by no other phenomena. Einstein's law is the simpler

our operations of measurement, because the appliances which we use for measurement are themselves part of the world. In the earlier part of this lecture we saw that the contraction of the arm turned from horizontal to vertical is not detected by measurements made with a yard-measure which shares the contraction; in the same way any anisotropy of the world does not appear in measurements of it by appliances which, being part of the world, share the same anisotropy. The law of gravitation therefore arises from the fact that a certain type of non-homogeneity and non-isotropy of the world can not come into observational experience, because it is necessarily eliminated in all observations and measurements made with material appliances. The orderly phenomena of gravitation are due to the *absence* of certain conceivable effects. We have been trying to find a key to the mystery; but the secret of the lock lies not in the key but in the wards.

law because it is consistent with what we now know of the general plan of world-structure; Newton's law could only be made possible by introducing a novel and specialized feature—a stratified arrangement of structure—which is not revealed in any other phenomena.

Maxwell's laws of electromagnetism afford an example of the other type. These, it is true, are stated as relating to the particular slices of the world of events, which are served up to us like rashers instant by instant. But they can be restated, without alteration of effect, in a form making no reference to slices. This is a very remarkable property of Maxwell's equations which was quite unknown at the time they were first put forward. It was brought to light much later by the researches of Larmor and Lorentz. In consequence of this Einstein is able to take over the whole classical theory of electromagnetism unaltered; he restates it so as to show how it applies generally and is not bound up with the purely terrestrial point of view, but he does not amend the laws. He metes out different treatment to the gravitational laws and electromagnetic laws, because he finds the latter already adapted to his scheme.

If I have succeeded in my object, you will have realized that the present revolution of scientific thought follows in natural sequence on the great revolutions at earlier epochs in the history of science. Einstein's special theory of relativity, which explains the indeterminateness of the frame of space and time, crowns the work of Copernicus who first led us to give up our insistence on a geocentric outlook on nature; Einstein's general theory of relativity, which reveals the curvature or non-Euclidean geometry of space and time, carries forward the rudimentary thought of those earlier astronomers who first contemplated the possibility that their existence lay on something which was not flat. These earlier revolutions are still a source of perplexity in childhood, which we soon outgrow; and a time will come when Einstein's amazing revelations have likewise sunk into the commonplaces of educated thought.

To free our thought from the fetters of space and time is an aspiration of the poet and the mystic, viewed somewhat coldly by the scientist who has too good reason to fear the confusion of loose ideas likely to ensue. If others have had a suspicion of the end to be desired, it has been left to Einstein to show the way to rid ourselves of these "terrestrial adhesions to thought." And in removing our fetters he leaves us, not (as might have been feared) vague generalities for the ecstatic contemplation of the mystic, but a precise scheme of world-structure to engage the mathematical physicist.

FAST AND FAMINE

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IN a strict sense an organism experiences inanition whenever it subsists on material previously stored in its tissues. Such a contingency may be forced upon it by circumstances or may be embraced through a voluntary impulse. As a deliberate act of total abstinence from food, inanition possesses elements of dramatic effect. In primitive times it was a sign of miraculous and supernatural gifts attributed to the faster, shedding glory of heroism on his deeds. Founders of religious movements were wont to fast for long periods, which doubtless enhanced their prestige for leadership and sanctified their commandments. As a biological phenomenon, however, inanition presents little of either the spectacular or of the heroic, and as a sociological fact it is common and insidious in its effects.

It is erroneous to suppose that during inanition the processes of nutrition are interrupted. Obliged to subsist wholly or in part on accumulated reserves contained in the tissues, the fasting organism is nourished just as truly as if it lived on the fat of the land. But now it is being nourished from within, not from without. Fed or starved, the living organism is governed rigorously by the law of conservation of energy. To maintain its body temperature, to perform vital functions (heart beat, respiration, secretion, etc.), to produce mental and physical effort the potential energy of food-stuffs must be transformed into the various forms of kinetic energy. The organism can not create either matter or energy, and failing to find this from without must use up its own potential energy. Every organism contains in its tissues a source of energy in the form of rich deposits of nutritive substances, which constitute the common foods when they serve to nourish another organism. Thanks to these large deposits, the existence of an organism is not readily endangered through abstinence. Since the metabolic processes obey the usual physical laws, inanition must be regarded as a special—perhaps, the simplest—form of nutrition.

The three chief objects of nutrition are to furnish matter for organic growth and repair of incidental wear and tear of the tissues, to supply energy for maintenance and energy for work. These objects are likewise attained under the conditions of inanition.

Active growth and regeneration are not incompatible with inanition, and the wear and tear, at least in some organs, is so completely repaired as to evade for a long time the effect of nutritional stringency. Inanition does not preclude the ability for extreme and sustained exertion.

According to the mode of origin we can distinguish three types of inanition: First, physiological inanition, which is a normal, regular occurrence in nature. This type of inanition constitutes usually a definite phrase in the life cycle of the animal. In the life of certain animals it also appears as a regular seasonal event or it accompanies the periodical recurrence of sexual activity. Next, pathological inanition of various degrees of severity associated with different organic derangements. It may result from some obstruction of the alimentary canal (esophageal stricture), from an inability to retain food (vomiting), from imperfect utilization owing to rapid elimination (diarrhea), from excess destruction of body tissues (infectious fevers), or from refusal to take food either because of loss of appetite or mental disease. Considering the many variations of inanition possible, it is not venturesome to say that nearly every disease presents a case of pathological inanition. Finally, there are a number of instances of abstention which for convenience may be grouped under the designation of accidental or experimental inanition. In this category, of course, belong all individual experiences of fasting which have been the subject of carefully conducted scientific investigation. Indeed, our knowledge of inanition is derived almost exclusively from laboratory observations.

Under the condition of total abstinence the organism depends largely upon its reserve material. This condition, however, is neither the most common nor the most important aspect of inanition. Profound alterations in the metabolic processes are occasioned when the organism is deprived of some peculiar—though quantitatively insignificant component of the diet, or when the food fails to supply matter and energy according to the actual demands of the organism. In the last case, especially, the reserve deposits of the organism will be insidiously exhausted. It is obvious, therefore, that we must discriminate between complete, partial and chronic inanition.

When inanition assumes the proportions of a mass experience we are no longer confronted with a purely biological phenomenon. Inanition becomes a sociological problem. The biology of inanition has the same significance for the sociological problem as the physiology of nutrition in general has for the economy of national feeding. The information gained from a study of the individual furnishes a most valuable basis for grasping the significance of the

problem and serves as a dependable guide in the search of a rational solution. In either case, however, the sociological condition is not merely a multiplication or a summation of individual experiences. As a sociological phenomenon, therefore, inanition presents a distinct and much more complicated problem. One can not intelligently deal with this aspect of the problem unless the fundamental fact is grasped of the influence of the economic forces in grouping individuals into classes living under a distinct social environment.

As a physiological phenomenon, inanition is invariably of the type of complete abstinence, the nutritive deposits of the organism furnishing the only source of energy and matter. Animals which experience inanition periodically have developed, probably through adaptation, a tendency to acquire during the feeding season large stores of fat. Physiological inanition is frequently of very long duration, for which a large supply of nourishment is indispensable. In hibernation, owing to the very low degree of metabolic activity, the nutrient deposits are used up sparingly, but physiological inanition may also be associated with vigorous activity.

Under pathological and accidental (experimental) conditions we encounter inanition in its numerous variations, ranging from total abstinence to some specific dietary deficiency. Chronic inanition, occasioned by the failure of proper balancing of the organism's demands and supplies, and partial inanition, determined by lack of some element vitally important for the normal functioning of the organism, both underlie many pathological states. A number of diseases have been traced in recent years to specific substances (vitamins) wanting in the diet, and must be regarded as cases of partial inanition. Chronic inanition, on the other hand, is a common physical basis of many ills, like dyspepsia, general debility, loss of nervous stamina, depression and fatiguability, neurasthenia, all of which flourish in the organism whose reserves have been persistently and insidiously sapped.

Strictly speaking, chronic and partial inanition are primarily laboratory occurrences. By this is meant that inanition of a definite type can generally only be produced under conditions amenable to experimental control. Inanition as a social phenomenon is, as a rule, neither simple nor definitely circumscribed, though one finds such instances, too. In certain social strata it would be impossible to determine whether the population suffers from chronic or partial inanition in the sense attributed to these terms. Among our industrial population the earning capacity and the cost of provisions are not adjusted with the sole view of producing for them the necessary quota of energy. This adjustment is left wholly to the precarious workings of the law of demand and supply. It is pro-

verbially true that this adjustment is neither quick nor prejudicial in favor of the economically dependent class. Chapin's report on the standard of living among workingmen's families gives ample evidence of widespread undernourishment. The actual conditions must be much worse than one gathers from the report because the undernourishment is calculated on the basis of food purchased. This leaves out of consideration a very essential factor, namely, the nutritive quality of foods sold in the poor sections of our cities. Where parsimony cuts down on quantity it is practically certain that the dietary quality is likewise degraded. The result is a combination of chronic with partial inanition. From a sociological point of view, abstinence from food is practically unimportant, while the ever present and common partial and chronic inanition blend into the insidious destroyer of life and happiness—the dreaded malnutrition.

Abstinence under compulsion of circumstances is fortunately a rare thing. It belongs in the sphere of accidents, and the suffering it produces is probably as much due to panic as to hunger. Where the abstinence is self-imposed by voluntary choice, and there is nothing in the way of interrupting the fast at any moment, the presence of hunger pain is generally denied by the faster. Were the sensation of hunger in inanition completely dulled it would be difficult to account for the fact that starved animals resume feeding at the first opportunity. We should also fail to comprehend the compelling force of the hunger urge which has been the great factor in all migrations, both human and animal. The question naturally obtrudes itself as to whether or not the sensation of hunger persists during inanition. Clearly one must differentiate between hunger and appetite. One is a primitive sensation common to all living organisms, the other doubtless is an acquisition depending on the degree of mental development. It seems improbable whether civilized man really knows the sensation of hunger. He takes his food in conformity with an established custom at stated intervals and irrespective of his actual needs. His whole existence is a cultivation of habits, and the change of habit is always apt at first to cause discomfort and a feeling of want. Irish or Bavarian peasants accustomed to their bulky diet of potatoes and bread suffer greatly when they are given a small quantity of highly nourishing food. Likewise, persons who have habitually underfed themselves are much discomforted when they are put on a sufficient diet. Appetite and subjective feeling are evidently unreliable guides in the matter of nutrition.

Hunger, on the contrary, is an instinctive demand for nourishment akin to the sex craving. The former is concerned with the preservation of the individual, the other with the preservation of

the race. Hunger is a powerful urge common to all organisms irrespective of their degree of evolution. It is probably as strong in the protozoan as in the rapacious beast of prey.

The mechanism of the hunger sensation in the higher animals has been elucidated by the brilliant researches of Cannon and of Carlson. The sensation of hunger and the subsidiary symptoms—epigastric pain, faintness, nausea—are associated with periodic tonic contractions of the empty stomach. The objective method of recording these gastric contractions reveals that the rhythmic tonic spasms generally associated with the painful hunger pangs continue unabated, or may even become accentuated, during inanition. This important fact has been disclosed by Carlson's collaborators in experiments with dogs, rabbits, frogs and turtles. Carlson himself demonstrated the persistence of strong tonic contractions reverberating through the conscious processes of a human subject who fasted fifteen days, and in his own person in a fast of shorter duration. It is nevertheless a fact not to be disregarded that whenever fasting has been practiced for therapeutic purposes and in the case of the professional fasters the hunger pain and discomfort disappeared after the first several days of inanition. It is difficult to reconcile the lack of desire for food and hunger with the persistence of the hunger contractions. In the diseased organism this may perhaps be accounted for on the assumption that the hunger contractions are inhibited through the bad taste in the mouth. In a number of diseases the absence of contractions has been experimentally demonstrated. The author's own experience has been that he can endure a brief fast of a few days without the least discomfort when he is not feeling well, but in a healthy condition the reaction has always been extremely painful. It is indeed very doubtful whether a healthy individual, with a vigorous demand for nourishment, would willingly endure the hunger sensation unless he was dominated by some powerful emotion. The bravado of the professional faster, the auto-suggestion or fixed-idea of the protagonist and neophyte of the faith of the all-curing potency of inanition, the sublime egotism of the martyr, may all prove effective in actually inhibiting or at any rate masking the hunger pain. Strong emotions, such as anger, fear, worry, excitement, exercise a strong depressing influence on hunger sensations. An over-refined estheticism of appetite may also act as a deterrent to the instinctive craving for food. One should not forget that inanition may result from just such emotional conditions. On the other hand, an exacerbated hunger sensation will completely dominate the conscious processes. Spurred by hunger, animals become daring and aggressive and forget fear. Human beings likewise quickly

unlearn the gentle arts of social intercourse under the urge of the hunger whip. They grow cantankerous, egotistical and brutal.

We know of no factor more potent in completely repressing the hunger urge than the sex emotion. It is a familiar fact, of course, that children at puberty lose their appetite for food. Love and passion in full bloom may also occasion protracted undernourishment. Niclot, in an interesting discourse on the expression of love in ancient literature, refers to the type described by them as "consumptive love." The victim of the passion was thought to be under some supernatural spell. According to Theocritus the physical consequences of this consumptive passion are often very profound. The person fasts for days, and, if his passion meets with an insuperable obstacle, will be reduced to skin and bones. The person becomes the victim of emaciation, progressive breaking down of force, insomnia, photophobia, of an instability of purpose and desire resulting from a disintegration of his will power.

A most striking instance of prolonged suppression of hunger in mammals under the compelling force of the sexual impulse is recorded by Parker. The Alaskan fur-seal bull neither eats nor drinks for about three months in the year, during the entire breeding season. This is the more remarkable because at all times the seal are within reach of food. Living in a state of great excitement, fighting off intruders, chasing mischievous "bachelors," keeping jealous guard over his "harem" of cows, the sexually hyperactive bull experiences complete inanition. Parker relates that "by the middle of June the great majority of the full-grown bulls have established themselves on the beaches to await the coming of the cows. At this stage the bulls are in marvelous form. Their pelts are heavy and firm and their bodies in prime condition. In weight they are not far from 400 pounds. They seem to be possessed of inexhaustible energy . . . Many of the bulls have been on the beaches from May, and during that period between the time of their arrival and the end of July or early part of August, they touch no food. This fast of well over two months coupled with their incessant activity drains them of all their stored energy. Their fat disappears, and they are reduced to almost skin and bones."

Acute inanition as a voluntary act is practiced either by professionals as a feat of endurance, or by crank reformers who see in inanition a panacea for all ills of the flesh. Laboratory experience with fasters as well as long fasting among followers of certain religious sects proves that no harm can befall the healthy individual who abstains from food. The vigorous individual has a thoroughly healthy disregard for all problems of nutrition and is not likely to indulge in fasting as a pastime. Indiscriminate fast-

ing, however, of patients whose strength is already impaired ought to be discouraged. In the hands of the skilful practitioner total abstinence from food may prove a wonderfully effective weapon in restoring health. The therapeutic value of inanition, however, should be studied experimentally and not be left to the judgment of amateur enthusiasts. The practical value of inanition will never be fully utilized until both the lay and the medical profession lose their instinctive fear of fasting. The experiences of recent years which through the medium of the press have reached a large audience will in course of time alleviate the entirely unjustifiable fear of abstention from food for longer periods.

The biological fact that under inanition it is the weakest parts of an organism which are the first to undergo destruction and are eliminated from the body may be safely put at the foundation of the therapy by this means. It is doubtless true that it is a rational therapy in affections of the alimentary canal. Through its tendency to lower the body temperature, inanition would be especially valuable in inflammatory involvements of the gastro-intestinal tract, as in typhoid or diarrhea. Guelpa was among the first to appreciate the importance of inanition in the relief of diabetes. The system now scientifically established by Allen is generally recognized as an effective means for combating this disease.

Since emaciation frees the organism of the excesses of inert material in its tissues, it is often a great boon. The study of physiological inanition should dissipate all terror of a possibility of endangering existence. Laboratory as well as clinical experience corroborates the rejuvenating effect of inanition. If not too prolonged, inanition is distinctly beneficial and may be useful in overcoming somnolence and lassitude as well as in improving the fundamental organic functions (circulation, respiration) muscular strength, or the acuity of the senses. To understand this beneficial influence we may imagine the organism as a wayfarer starting on a long journey provided with a load of victuals. Crouching under his heavy load, he trudges along slowly and with difficulty. His heart is overworked, his respiration is forced, and every obstacle in the road quickly wears him out. Gradually his supply of victuals is consumed and, as the burden becomes smaller, his step grows lighter. He advances more quickly and overcomes obstacles more easily because his muscles are less fatigued. The organism's efficiency improves in a similar manner when the excessive load of inert material in its tissues is used up. The training of athletes bent upon creating a high degree of strength and endurance is likewise concerned with a reduction of the inert fat deposits and a simultaneous building up of the muscle mass. The salmon furnishes us another interesting example. At the time they commence

to migrate from the sea towards the streams their muscles are thoroughly encumbered with huge masses of fat. Fasting all through their long journey, which lasts many weeks and months, they are in a much emaciated condition when they get to the upper reaches of the rivers where the currents are rough and swift. Freed from the fat, however, their muscles are now agile and nimble, and it is at this time that the salmon display marvelous endurance and skill admired by all sportsmen, in progressing steadily against all the odds of the tumultuous current, water-fall and obstructions.

Except where it occurs in nature, acute inanition is primarily an individual experience. Therapeutically it will remain relatively unimportant until education overcomes the innate fear and distrust for the method, and from a sociological standpoint it is practically of no significance. Where it affects large masses, however, inanition is a corollary of certain evils deep-rooted in the social organization; it is an unwelcome and perpetual visitor in the homes of the lowly, but it is not the beneficial agent we spoke of. Here it appears as the insidious malnutrition which silently saps and undermines the health of the mass. It does not signalize its presence by engendering a violent urge for food; it just corrodes the powers of resistance, remaining unnoticed often until the wreck it causes is hard to redeem. It does not kindle up the latent hunger instinct to defy fear and hazards; it blights ambition and gnaws away the threads of social ties by generating an irritable, cantankerous predisposition.

Frequently malnutrition results from nothing else than ignorance. The lack of comprehension that the law of conservation of energy applies to the functioning of the living organism is doubtless responsible for the fact that some deluded folk either reduce their consumption below actual needs of their body, or else consume stuffs entirely inadequate from a physiological standpoint. Generally under such circumstances their vitality is nibbled away by slow starvation. Insufficient consumption of nourishment gradually becomes a vicious habit. The dulled state of the psychic mechanism of appetite and the discomfort actually experienced from taking larger quantities of food are mistaken for the true sign of the organism's demands. The enfeebled appetite misguides the undernourished person to scrimp still more in his diet. The physical consequences of this malnutrition are the great depression of bodily activity, general disinclination to exertion, easy fatiguability, as well as anemia and poor circulation, neuritis and various neuroses. It is also a well-recognized fact that the undernourished individual craves for every kind of stimulant, a matter which gains considerable importance when the malnutrition extends to large groups of the population.

One can derive much hopefulness from the fact that the effects of malnutrition, if early recognized and combatted, are evanescent. With proper care and abundant nourishment the organism can be built up again. In his official report on food conditions in Germany, Professor Starling ascribes the collapse of national resistance to the circumstance that the urban population (more particularly, the working people) was starved, and this generated widespread apathy, listlessness and hopelessness. He expresses the opinion that this population of Germany would have to be nursed back to health just like a sick patient and that at least "one or possibly two generations must pass before Germany can recover her former efficiency."

A new and serious source of malnutrition has arisen in our modern industrialized civilization. By the implacable economic forces women have been drawn away from their traditional place in the home into the turmoil of industrial production. At the same time the factory has intruded itself into the home and has preempted much of the woman's function of preparing the family's food. The manufacture of foods dispensed in cans and ready to be served has insinuated itself into the homes of the people to such an extent that it has become literally true that many households can nowadays be conducted with the aid of two implements—the corkscrew and the can opener. The evil of these industrial conditions is not only in the circumstance that the younger generation is deprived of proper maternal care, but also in the fact that tinned goods, when these are the staple article of diet, owing to qualitative deficiencies, may produce the effects of partial inanition. A better understanding of the fundamental principles of nutrition would perhaps offset this danger to the health of the population.

However, ignorance of the essentials of the physiology of nutrition is not the only nor the gravest peril. This can more or less be overcome effectively by disseminating information. Unfortunately, the great peril of malnutrition is rooted much deeper in poverty coupled with ignorance, and against this conspiracy the spread of the gospel of nutritional science can accomplish little. Furthermore, as a social phenomenon malnutrition is not simply a matter of either insufficient or improper nourishment; it is the sinister combination of blighting influences of poverty—overcrowding, underclothing, an unhealthy and unhygienic environment. Here is the fertile soil on which tuberculosis reaps its ghastly harvest.

Visiting Germany immediately after the collapse in the late war, Harris was impressed with the blessings in disguise which the few lean years have brought to the people. He found that there was a striking decrease in the number of patients suffering from

chronic nephritis, chronic ailments of the stomach and liver, from Bright's disease and diabetes. He was generally informed by practitioners that they "did not have gout any more in Germany." Had Harris looked at the matter from the perspective of the sociologist, he would have noted that frugality benefited a class of people with whom eating was generally a social grace if not a central interest in life. The diseases mentioned are proverbially the price paid for the social privilege of overeating. As for gout—a well-recognized rich man's disease—this has always been a badge of class distinction. The reduction of the diet of the chronically overfed population to the limits of a healthy and normal basis has very evidently been a benefit. But in the lower strata of society, where the population lives in the precarious region of the minimum requirements, the increased stinting in nutrition manifested itself quickly in an appalling spread of malignant tuberculosis, especially among children, in increased death rate and general physical degradation. It is of this working population of Germany that Professor Starling says that it would have to be nursed back to health and physical efficiency.

A striking example of wretched physique resulting from the wretchedness of living conditions is presented by the Jews of Poland. Their physical strength, their muscular power has diminished in each succeeding generation; their blood is poor; their stature is small, shoulders and chest narrow. Many have an emaciated, pallid look and even show signs of racial decline and degeneracy. Held back by various disabilities, crowded in the Jewries of Poland, with limited opportunities for gaining a livelihood, they have literally been the victims of malnutrition for generations. Their poor constitution, physical frailty and stunted growth make them manifestly unfit for heavy work. Leroy-Beaulieu says of them: "Few races have so many men who are misshapen and deformed, disabled, or hunchbacked, so many who are blind, deaf-mutes, or congenital idiots." Close inbreeding owing to marriages between near relations can hardly be held responsible for this physical degeneracy. The inbreeding only accentuates the evils of age-long confinement, of lack of exercise, of lack of pure air, of lack of healthy social environment and above all else of wholesome nutrition. The rôle played by malnutrition in producing racial deterioration of the mass of Jews, especially in the Polish ghettos, can best be appreciated from the fact that investigation of their living conditions has shown that they were so poor that for generations they subsisted upon nourishment below the actual minimum requirements. Tchubinski actually found that the Jews of Little Russia and Poland consumed less food than either their Greek Christian or Polish Catholic neighbors.

Transferred to a less forbidding environment, the inherent recuperative powers of the organism under favorable nutritive conditions show remarkable effects already in the first or second generation.

The influence of religious fasting upon the health of the population is little realized. The complete inanition practiced by individual devotees or even by whole ascetic sects is of no concern in this connection. From the point of view of physical deterioration it is the malnutrition associated with religious custom that should be mentioned. Even in this respect the effect is different in different classes of society. In the Middle Ages it seems that the rich men could forego fasting and obtain absolution for a price. Mass starvation from religious devotion is an important phenomenon in Greek Catholic countries. Considering that three days in the week are fast days, besides several protracted fasts at various seasons, it is safe to say that fasting is prescribed for about one half of each year. The fasts might be a benefit if they only limited the consumption of meat. In the Greek Catholic Church, however, the prohibition extends also to eggs and dairy products. As usual the poor population is especially the sufferer under these restrictions. The young children in particular are the victims. Medvedjev found that the boys and girls of school age all show a loss of weight during the fast seasons. The malnutrition of the mass of the people is so great that women are unable to nurse their babies, and there is usually an enormous mortality among the infants. Scurvy and pellagra, eye-diseases (night-blindness?) and typhoid are common incidents among the fasting population. Alcohol was consumed in unusual quantities by the poor people to still the constant irritation which marks their malnutrition. The peasantry deadened itself with drink.

Famine is the most acute form of malnutrition. It is truly one of the cruelest scourges of mankind. It would be impossible to estimate the extent of damage in terms of physical suffering and ruin. Those who fall by the wayside are soon enough forgotten, but famine leaves a trail of human derelicts, of cripples, of blind and feeble, of a generation with undeveloped sinews and brain. The fundamental cause of famine is in all cases probably economic, but crop failure is the immediate cause of the situation when millions of people are without means of subsistence. Those who write about famine vary in their opinion as to whether this is punishment meted out by an unpropitiated god or should be laid squarely at the door of ignorance and oppression, greed and exploitation. In certain countries famine is practically an endemic occurrence. And, strangely enough, the classical lands of famine are also under

foreign dominion, like Ireland and India, or under a tyrannical exploitation as Russia was in the time of the Czars. In India famine played a more momentous and at the same time more tragic part than either war or pestilence. It spread at times over many thousands of square miles, affecting at once millions of people. Since its domination by the East India Company and in the subsequent fifty years under the Crown, India suffered twenty-two great famines and a number of less extensive scarcities. In the great famine of 1876 alone about five and a half million people died in excess of the usual death toll, though, of course, it would be altogether impossible to discriminate how many deaths were directly due to starvation and how many to various diseases brought on by severe malnutrition.

Famine is not merely destructive of health and physique: it is in a still greater degree a disrupter of morale and character. In the sharp struggle to maintain life all scruples are overcome, neighbor is against neighbor, and the strong are ruthless towards the weak. With wonderful force of simplicity does a thirteenth century Russian chronicle relate the horrors of the famine in the Novgorod province: "We were all in a fury of irritation; a brother rose against his brother, a father had not pity for his son, mothers had no mercy for their daughters; one denied his neighbors a crumb of bread. There was no charity left among us; only sadness, gloom and mourning dwelt constantly within and without our habitations. It was a bitter sight, indeed, to watch the crying children, begging in vain for bread and falling dead like flies."

The aftermath of famine, however, is still more appalling. Little actual information can be gathered of the after-effects. Prugavin tells of the many thousands of peasants afflicted with scurvy, typhus, spotted fever, influenza and diarrhea in the terrible famine which spread over the central provinces of Russia in 1898. Even long afterwards nearly all the children from the famine area suffered from various eruptions, rickets, diarrhea, purulent inflammation of the eyes. The doctors who went into the pestilential districts to bring succor to the famine victims have noted the unusually large number of people with severe eye diseases. The great Irish famine of 1848 likewise left a trail of blind men and women in its wake. Dr. Emmet reports that the number of blind increased from 13,812 in 1849 to 45,947 in 1851. The recent developments of the science of nutrition have shown that such affections of the eyes are invariably associated with the lack in the diet of a substance known as vitamin A, and its absence is a concomitant of malnutrition.

ZOOLOGY AND THE COLLEGE CURRICULUM[1]

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EVERY teacher of zoology must at times experience a feeling of dissatisfaction with the status of this subject in the general educational system, or if not with its status in the educational system, then with the almost total ignorance of the public regarding it. For whereas animal life furnishes one of the largest factors in man's environment and certainly one of the most intensely fascinating factors, one finds but small place or none at all given to the subject in our high schools and a comparatively small interest taken in it in our colleges and universities, while in our graded schools few of the teachers attempting to teach it as nature study really know enough about it to make their work dependable or desirable. And accordingly we find the general public so ignorant of the subject that it becomes the victim of all sorts of pernicious yarns and trashy animal stories which, in the credulous, fire the imagination to a point of irresponsibility, while in the critical they dull the mental appetite to a point where the mere mention of the subject is repulsive.

This seems a strange predicament in which we, who are attempting to lead forward along the trail first blazed by such men as Linnæus, Schleiden, Schwann, Lamarck, Agassiz, Darwin and their like, find ourselves. And I pause to ask you why we of the twentieth century, who have more to look back upon, more to look forward to and more to work with than all that have lived before us, are in spite of these great advantages unable to make this large and most interesting of all subjects so appeal to the good sense of the people as to receive at least its proportionate share of attention in the curricula of our universities and from the students of higher education.

I have taken the trouble to inquire of a number of our leading universities as to what percentage of their total enrollment takes at least one course in zoology. And according to the replies received the percentage ranges from 3 per cent. to 27 per cent. with an average of about 13 per cent. This means that about one in

[1] Read before the Kansas Academy of Science, February, 1921.

eight of our supposedly educated men and women have during their educational career made at least some study of animal life. My first question is: Shall we agree that the world of animal life is of such minor importance that seven out of eight of our educated public should not even be instructed in the primary elements of the subject? And second, if it is not so unimportant, why do so few study it? It seems to me that it is up to the teacher of zoology to answer this question.

When we consider the relationship that exists between zoology and sanitation, hygiene, medicine, agriculture, horticulture, forestry, household economy and between zoology and recreation, we conclude that from the practical viewpoint it is important that the average student should study animal life. And when we consider the relation of the scientific method in zoology to the history of thought we are sure that ministers and teachers should be familiar with the subject. Looking at the wealth of recreational enjoyment and the cultural aspects of a knowledge of animal life we wonder that any student is content without it. And yet the fact remains that only one in eight of our students studies zoology. The cause for this lack of interest in zoology is, I think, not difficult to discover. The general course as given in our colleges and universities is primarily designed to meet the needs of two classes of students, *viz.*, those who are preparing for research or teaching and those who are preparing for the medical course. Such a course must of necessity be quite technical—too technical to appeal to the average student who is looking forward to a career in one of the commoner vocations, such as agriculture, commercial life, home-making, etc. (And yet we all know that a knowledge of animal life is of great importance in the educational equipment for any of these vocations.) But we find our departments sought out by the premedicals, prospective biology teachers, a few unusually broad-minded students of agriculture and practically no others.

Now from the zoologist's point of view there are about three objectives which justify the teaching of zoology: First, the research objective or the preparing of investigators who shall extend our knowledge of animal life; second, the economic objective or the preparation of men for the field of applied zoology, and third, the cultural objective or the equipping of men and women for a larger and fuller appreciation of the organic world about them—an enriching of life, the making of a better and more intelligent citizenship.

These three objectives are very closely related, for there is little value in extending our knowledge of animal life unless it may eventually lead to an application of such knowledge to the problems

of human welfare, either in an economic or in a cultural way, while both the economic and the cultural objectives are dependent upon research for their greatest achievements.

Now let us examine fairly for a few minutes our system of teaching zoology in its relation to the needs of students. Student No. 1 comes who desires to become a research zoologist or a teacher in a university. We start him in our general course and then he passes through one advanced course after another of morphology, histology, embryology, cytology, etc., until we turn him out a finished product ready to enter his chosen field. So far we are all right. But this class of students is small, representing probably 5 per cent. or 6 per cent. of the student life which comes under our tuition. Student No. 2 comes, representing perhaps 50 per cent. to 75 per cent. of our student life. The desire of this student is not to become a specialist but merely to prepare for a larger and broader life in one of the commoner vocations, perhaps to be a merchant, a housewife, farmer, lawyer, minister, salesman, banker, a musician, a painter or to enter any one of a score of other vocations. The needs of this student will be met by a study of the general principles of zoology in a not too technical way, a study of habits, habitats, animal associations and relationships, and the natural history of the local community, state and nation. We have but one thing to offer and that is our general course which is adapted to the needs of the prospective professional few. We can hardly expect a prospective merchant, for instance, to elect a course primarily designed for the medical profession, and yet we know that zoology in its broader aspects has much to offer even a merchant. But, not desiring to wade through the maze of dry details, this student who represents the bulk of student life turns away and studies no zoology at all. Next comes student No. 2 who purposes to prepare for work in applied zoology. He may become an entomologist, an animal breeder, a sanitary engineer or some other specialist whose work is wholly or in part founded upon zoology. For this student we have courses suitable and in due time he has gone under the tutorage of the specialists in his chosen line and comes forth prepared for his work. But here he faces a new difficulty. Two conditions are necessary to the successful application of scientific knowledge: First, a prepared specialist, and second, a responsive public. We have met the first condition, but the second we have not met, and when our young specialist goes into the field he finds himself surrounded by a suspicious and superstitious ignorant public who lack just one thing to make them his enthusiastic supporters and that one thing is knowledge—a knowledge which is lacking largely because

when student No. 2 came to us we had nothing to offer but a specialist's course and so he turned away.

Speaking from the standpoint of one who has had some little experience in three different states as a practical demonstrator, I submit to the practical specialists who may read this the proposition that were it not for those very few farmers and others whom you find in the various communities who have some special knowledge of the subject in which you are working, the demand for the services of a specialist would indeed be small. And let us not forget that only one in eight of our *university trained men and women* acquire this knowledge while with us. So we see that one of the weaknesses of our system is that it results in a sort of professional suicide.

And this suicidal tendency is not limited to the realm of applied zoology, for when our high school teachers go out with only their technical training they not infrequently find themselves unable to successfully present their subject to boys and girls who are eager for a knowledge of natural history, but not capable of attending on those phases of the subject which are so often presented to the exclusion of more fascinating aspects which may be equally scientific. And to me it seems unfortunate that so few of our high schools offer any work whatever in zoology. The general science course does not make up this deficiency, for it attempts so many things that it must of necessity consist mostly of "general" and but little of science.

Zoology furnishes a world of interesting and practical material of sound worth both from a cultural and from a practical viewpoint. And I firmly believe that the subject is so important in its relation to human life that the majority of the students of our colleges and universities should take a minimum of six credit hours in the subject, out of the 120 hours required for the A. B. degree. I do not believe that this should be a requirement, but I think that the subject should be made to appeal to the average student as a necessary part of his or her equipment for life.

And now arises the question: How can the subject be taught so as to meet the needs of the general student and yet not sacrifice those technical qualities which are so essential to the professional zoologist? In answer to this question I wish to suggest a line of procedure which is slightly different from that usually followed. I believe that in order for our department to function properly there should be established two different elementary courses in zoology, the one preparatory to research, medicine and applied zoology, and the other designed to give a cultural and practical knowledge of the subject such as would best serve the needs of the men and women who enter those vocations which employ the bulk

of our citizenship, such as merchants, agriculturalists, housewives, lawyers, salesmen, grade school teachers, ministers, lecturers, etc. The former might be much the same course as now given in most colleges or like that outlined in Dr. Shull's new text, while the latter should deal with the same principles in a more general way and should treat much more at length the subjects of distribution, habitat, habits, animal associations, taxonomy of the familiar forms and questions of economic relationship. This course should present a greater mass of material than is presented in our present general course, but should require less of a technical nature. *It should not be an easier or lighter course but merely of a different nature with a different purpose.* We need no less of the technical but we do need more of a general knowledge of animal life and we need to make this general knowledge reach a far greater number of people. We need to develop in a larger number of people a proper respect for the scientific method in thought and in living. We need to train more people in the art of finding proper recreation in the out-of-doors. I believe that there is a very definite relationship existing between these phases of the subject of zoology and *good citizenship.* And whatever may be the secondary and tertiary aims of higher education its primary aim must always be that of developing the highest type of *citizenship.*

To the professional zoologist it is important to know the chemistry of certain metabolic processes in certain animals, but to the average university graduate it is more important to know the feeding habits and home life of those same animals and their relation to his interests. If we are to raise zoology to its proper place in the college curriculum we must raise it to its proper place in the lives of those whom we teach; and to do this we must realize that it is just as important that a college graduate know the difference between a nuthatch and a sapsucker as it is that he know the difference between a chemotropic and a thigmotropic reaction. In a very widely used college text-book on zoology and one which may be taken as a type, thirty-six pages are devoted to the phylum coelenterata. Of this amount approximately one page is given to the discussion of coral reefs and their formation and six lines are devoted to the "economic and geological importance" of the group.

In another very recent and to my mind a very excellent text the author has seen fit to append a glossary of 1,237 technical and historical terms which are used in the volume. I presented this list to two college freshmen who had made grades slightly above the average for their class in a standard intelligence test. They had both finished the first semester's work of their freshman year,

and my test proved that they *thought they knew* the meanings of 314 and 354 words respectively out of the list of 1,273, and in looking over the lists of words whose meaning they felt they knew I noted that a large part of them we had used in a course in physiology during the first semester of this year.

On the basis of these findings it would certainly be conservative to say that a freshman beginning zoology would have to deal with a thousand new and technical terms in the mere reading of this text. I am not going to say that this is too much to ask of a student looking forward to a professional career in a field where a vocabulary of technical terms is necessary; but I do say that the mastery of such a list will leave but little time for the acquisition of facts and the grasping of principles which are of so much greater value to the *average* student than at least half of these terms would be. I am not trying to condemn our present general course in zoology (though I do agree with some of the current suggestions as to how it may be made better than it is at present). But I am trying to point out what seems to me to be a very great need in our field of endeavor. We surely have two quite distinct problems, and I believe they can only be properly met and solved by attacking them in two different ways.

In my own experience in leading classes in field zoology I have found a large percentage of the general public eager for a knowledge of natural history and I have been surprised at the effort which students and even business men were willing to put forth to acquire that knowledge. The course I am suggesting would furnish a sufficient introduction to the subject of natural history and methods of studying it to satisfy this desire, and would furnish an entrance to more advanced courses in the natural history of the various groups. It seems to me that there is entirely too little stress laid upon this phase of zoology to-day. The great builders of our science have all been men of a very wide knowledge of natural history and therein lay their secret of success as teachers and students of the subject.

It seems a rather serious reflection upon methods when university graduates who have majored in zoology are unacquainted with the habits and relationships of the common animals of their own community. These same students are able to discourse at length upon subjects of histology and cytology, which is well enough, but why not both? I have known zoology teachers in high school holding degrees from our best universities who could not answer the simplest questions about the birds of their own campus and who did not recognize even the orders of common insects brought to them by their students. These teachers were well trained in some phases

of zoology, but should they not be able to carry their study out to where animals live without becoming embarrassed?

The other day in looking through a book on psychology which is the adopted text for our state of Kansas I found a "drawing" (by the author of the text) of the nervous system of a mollusk which is labeled and discussed as that of the earthworm. The author has a Ph.D. after his name; but I am not supposing that he earned it in zoology. The point I wish to make is that our courses are not studied by those specializing in other lines as often as they should be, and I fear we are partly to blame for this. A few years ago I discovered a rather gross inaccuracy in our commonly used text-books regarding the mouth parts of orthoptera, and in tracing it back I found that for fifty years this same error had been copied in one after another of our texts even down to the present day. All of which points to the fact that we are studying books and prepared sections more than we are studying animals as such.

The establishing of such a course as I propose would accomplish five things: (1) It would extend the knowledge of zoology to a very much larger group; (2) it would render applied zoology very much more effective by virtue of the increased knowledge of our subject among the general public; (3) by a revival of the study of natural history we should be led to a study of animals as organisms as well as cells and organs, which would render our work more scientific; (4) by a more widespread interest in natural history the safeguarding of our public parks against the encroachment of commercial interests would be insured; (5) with the increased interest in natural history and the consequent appreciation and upbuilding of public parks a much larger percentage of the public would seek outdoor recreation, which would inevitably result in a raising of our standard of health and in better citizenship.

TOIL AS A FACTOR IN HUMAN EVOLUTION

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THE sphere of toil is more comprehensive than that of modern labor problems and far more primitive. In fact toil dates back to the beginnings of life itself, when the most primitive unicellular organisms toiled to extract a livelihood from the inorganic environment. That the living cell of protoplasm toils at its ingestion, secretion, digestion, assimilation, excretion and many other life processes there can be not the least doubt. And in the same sense that the single-celled organism, both of long ago and of to-day, toils diligently for its livelihood, so also do their compounded, many-celled offspring toil in so far as the myriads of component cells are concerned, even though the resultant organism be the laziest man on earth.

The cell toils in either case, be it single or compound. It is not the fact of toil, therefore, but the nature of the toil which differentiates the lower from the higher organism, the toil of many of the cells in the complex organism being differentiated, or highly specialized, while that of the simple single cell is undifferentiated toil, generalized, or complete in all functions. The primitive man has in his body cells which perform but one function for him, while other cells perform another function, each of these cells, or group of cells, being highly specialized for its own particular task. The primitive man himself, as a unit organism, performs all functions of the living body, and is able to turn his hand or mind or other part to any performance he may choose, be it eating, playing, thinking, speaking, fighting, while many vital processes go on within him unconsciously.

The modern man is more or less civilized, whatever that means, and is battling with himself—or with others—as to how generalized, or how specialized, his work as a complete organism shall be. Shall he perform a varied and interesting group of tasks, bringing body, mind and heart into enthusiastic effort, or shall he specialize in but one monotonous task, repeated endlessly? Shall he be a complete organism himself, or a differentiated unit in a complex social organism composed of many men?

The question of the generalization or specialization of the toil

of the cell has had much to do with the evolution of the human being in the past. The question of the generalization or the specialization of the toil of the entire man will have much to do with the evolution of the future man, and will be considered later in this paper. Intermediate between these two extremes of the problem, we may ask what effect the changing nature of the toil of the animal of the past had upon its evolution into human form.

The nature of the toil of the individual affects his postnatal development quite noticeably. Just what affects his prenatal heredity is a question which constitutes a battle-field royal of scientific controversy, into which men have thrown more heat than light, and over which battle-field the obscure shadows of orthodoxy have shifted now here, now there, as one or another virile leader of thought has gathered his train of followers under the shadows of his intellectual garments, shrouding their more timid natures in the happy obscurity of the orthodoxy he has built about his scientific self even as the priest robes himself in his priestly robes. The orthodoxy of men of science has many times been as inexorable as the orthodoxy of men of religion.

This chance suggestion of science and religion, mentioned only by way of illustration, leads me to make the following brief comment as to the permutations and combinations one finds rung between the two. To-day one may find those who claim to be perfectly orthodox both in religion and science; one finds those who claim to be orthodox in science, but free lances in religion; those who are orthodox in science, and claim to have no religion; those who reverse any one of the before-mentioned combinations; those who are free lances in both science and religion; and those who are moved neither by the spirit of "standing pat" nor the spirit of revolt, but open-mindedly and diligently seek for all light and all comfort from every source, conscientiously rejecting all which is not light. With this comment I will leave the question of religion as a factor in human evolution for treatment in another paper.

All admit that variations are continually occurring within every species, human and all others. Whether the environment has or has not anything to do with the production of those variations, it has something to do with selecting those variations best adapted to itself. So with the animal whose offspring was destined to become man, the nature of its toil, somewhat more intelligent than that of others, must have had much to do with his selection and survival. The greater versatility and ingenuity shown in its toil certainly gave it advantages over its fellows who toiled more as the other beasts had toiled for ages past. However one may explain or leave unexplained the minute links in the chain of cause

and effect, few will deny that the changing nature of the toil of the man to be was at once both cause and result of his current evolution—among the many other causes and results. Other factors may have been of greater consequence than toil, some were certainly of less consequence, for by toil we mean the sum of all activities. In the case of man this included the use of implements and the better provision for safety, shelter and food supply.

Our flying mammals of to-day, the bats, were descended from mammals which never flew. The flight of bats is most strenuous toil, requiring great exertion and rapid physiological metabolism, and is most intimately connected with food-securing. Cut off the wings of bats in nature and they would soon perish. Our large swimming mammals of to-day, the whales, descended from terrestrial mammals of the remote past, depend absolutely upon their swimming powers in all their activities of life. The toil of these blubbery monsters is sometimes prodigious, yet very different in nature from the toil of their landlubber ancestors. The toil of our degenerate parasitic worms, now very erratic in nature, now very primitive, is quite unlike the toil of their more normal, non-parasitic ancestors of the past. Rob them of their chance to parasitize and they die. Man is not the only one that changing toil has influenced.

Continuous changes of toil in the past have been intimately associated with other continuous changes in the organism. In the present and in the future, equivalent changes in toil will be intimately associated with equivalent changes of other sorts in the nature of organism.

Whether one approaches the facts of evolution from the paleontological viewpoint, or from a very broad view of the creatures living to-day, their structure, habits and development, one can but conclude that the nature of the toil of any living organism has had, and will have in future much to do with that organism's evolution. Interesting as is the study of the history of human toil in the past, and its close connection with other changes in the life of our race, it is of even more importance to foresee the consequences to the race which different phases of human toil will produce. The labor problem of to-day is but one sector of a most vital question of toil which is facing us, now menacing our evolution, now smiling on it; threatening to lead us downwards, promising to lead us upward, or chancing to lead us in devious, tangled ways.

While many are working themselves half to death, and more are working strongly and bravely, with profit to themselves and

to others, very few are giving the subject of toil the clear, impartial and comprehensive thought which it deserves.

It is often and rightly asserted that sexual reproduction is one of the oldest vital functions, but toil is older than sexual reproduction. It is as old as nutrition, respiration, excretion—as old as life itself. Standing therefore in the most ancient rank it deserves the utmost consideration.

Old as life itself, the toil of the cells, by cooperation and differentiation, has made the hosts of complex organisms possible. By change, it has made the whale aquatic, the bat aerial, the parasitic worm a lazy, degenerate trouble-maker, the man a fine, free-thinking, faithful, joyous individual, the hymenopterous insect, in some cases, a peculiar, specialized individual, performing continuously a single task in a community. Man has shown slight tendencies to develop along each of these ways, though only recently successful in the air. The tendency to become a human parasite has often made an appearance in historic times, but fortunately has not become wide-spread at any time, except in localities where cretinism has been endemic. Modern industrial conditions urge upon the race, more strongly than ever before, the highly specialized, single task for the individual laborer on the pattern of the hymenopterous insect. Now with all our long and wonderful evolution from the single-celled organism to our present selves, and with all of our powers of cooperation and our love of race, we have succeeded so far in keeping ourselves intensely and roundly and joyously individualistic. And I believe that it is this strong individualism which has prevented human parasitism on any large scale. Our well-developed individualism is also responsible for our lordly spirit and all-conquering ambition, and the many and varied joys which come to an all around man in the world. How then shall we meet the many problems which the present labor situation, and the overcrowded, overcivilized cities are thrusting upon us? Shall some toil only with their brains and others with their hands? Shall some specialize in one single kind of brain work? To me, professionally an observer of the living organisms of to-day and a student of the life of all times, it seems infinitely wiser for every individual to round out his daily activities as perfectly as possible. A powerful and wise man among the ancients tells us to study the ant and be wise; he might equally well have told us to go to the tapeworm and not do as he does. While profiting by emulating the industriousness of the ant, we would lose the best which life has to offer by merging our individuality as completely as some ants have done. Hebrew history describing the ideal conditions of life prevailing under the rule of the wise

man who gave the advice about the ant, records that the people dwelt safely, every man under his vine and under his fig tree all the days of Solomon. This points to an individualism in which every person was something of an agriculturist on his own account. And truly, a small amount of agricultural activity daily would be a most valuable addition to the life of those who have it not. Hebrew prophecy, foretelling the ideal conditions to come, says that in the last days it shall come to pass that they shall sit every man under his vine and under his fig tree. To this every muscular lover of the open will say amen.

The modern science of dietetics has shown the world the value of a balanced ration of food both for man and for cattle. A scientifically balanced ration of activities for man is of even greater value. What should this ration include, and what exclude? Upon the answer to this question will depend our future evolution as well as our present happiness. To answer this question let each select three or four of the most ideal persons he knows or knows about. Let him then think of the several elements entering into the complete, well-rounded life of each of these persons, then add these together, and see what varied activities are necessary to exercise completely and regularly these varied elements of personality. The results will set you thinking, if you have an imagination, and you will next query how you can apply the results to your own benefit. And it is well for each one to think of the enrichment and evolution of his own life, within whatever narrow limits his prenatal heredity will permit. The younger he is when he thinks of this, the greater will be the personal gain, and, if it be not too great a heresy to suggest it, the greater the chance of passing on some slight portion of his acquired gain to his offspring, a slight chance, perhaps, and denied by many.

There is a tendency to-day to make of some a mass of brains and emotions, while causing others to be emotionless hands. While all believe in the superiority of brains over brawn, most would, if they had to choose one or the other, prefer to be a mass of living muscles without any brains than a mass of living brains without any muscles. It would be far less disturbing to the mind.

Watch some of our moneyed New England spinsters as they sit in the parlors or on the piazzas of their favorite New England inns, playing cards, knitting or just gossiping. Some of them are fast growing unable to walk a mile, and must sit in the deep, soft cushions of a car if they would go somewhere. But not all are so, for many are keeping themselves superbly "fit" in body, mind and soul. The whole man needs exercise daily, muscles, lungs, learning power, creative imagination, special interests, sym-

pathy, social interests, artistic tastes, musical, poetical, philosophical, scientific, and any other good tastes which the individual may possess, repressing all the while any morbid or unwise tendencies. This last mentioned elimination of undesirable tendencies is best accomplished, not by thinking of those things which one would eliminate, but by filling the life with such a rich variety of good activities that there is no room for the weeds in the well-planted garden.

While specialization does and will accomplish much which could not be done otherwise, the wise specialist will put a strict limit to the time he devotes daily to his specialty, and plant the rest of his daily activities as wisely as the best of all-round beings.

Adaptability to one's environment is not the panacea it is sometimes claimed to be. Without underestimating the value of versatility, we need only mention the guinea-worm and the cosmopolitan tapeworm as wonderful examples of adaptation to environment. The widely preached doctrine of being contented with whatever state one finds himself to be in may be pressed too far. It is far better to growl a little about your circumstances if growling will incite you and others to set to work to improve your environment. Introspective faultfinding may also start some wheels in motion for improving self by improving the quality and variety of one's activities, which we may call his toil.

Toil considered in this widest biologic sense as the sum of all activities of an individual, becomes an interesting challenge. Realizing its strong reactive powers upon the individual, and eventually upon the race, the spirited individual will exert his faculties to the utmost in securing a regimen of activities which will each day call into most harmonious play all his best powers. Instead of being satisfied to do with his might whatever may chance to come to hand, he will have a broad and very definite plan of action which will make him truly the architect of his own career, and will, at the same time, react most helpfully upon his associates. It seems reasonably certain that the most capable individuals will never be content to specialize to the extent which would convert them into mere elements in a compound or cogs on a wheel. Life for each individual should be a thrilling, joyous, strength-giving composite, supplying the purest air for his lungs, exercise in great variety for all his muscles, and calling into play his highest powers, intellectual, musical, religious and artistic.

The small farm, in combination with some intellectual profession either salaried or independent, will doubtless be the solution which many will try, as supplying both the physical foundation and the mental superstructure. On that same small farm, many,

if not most, of the necessities of life may be produced rather than purchased, and also some luxuries. It is the "vine and fig tree" idea. A few hours of varied farm and garden work, a few hours of concentrated intellectual work, a few hours of recreation and social activity, in the midst of an inspiringly beautiful landscape chosen for its pleasing qualities, and the whole pervaded by a worshipful, devoted spirit within the lucky fellow who had so ordered his life, would seem to round out the day most delightfully along the lines of progressive evolution toward higher and even higher attainments in the life of the individual and the life of the race.

The toil factor in evolution, old as any other factor, is as fundamental as any, and should be given full recognition in any plan for race improvement.

The problem seems all too simple when viewed thus in its entirety, from the beginning of life to the present day, from the single cell to the highest organism, but see how far your own life diverges from a simple, ideal combination of all the more important activities. The true test of your executive ability will come in making the ideal a successful and practical reality.

CITY GROWTH AND CITY ADVERTISING

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IT is a widespread impression in the United States that any live community can remain in its active and populating condition only by an extensive advertising campaign. This notion persists largely, no doubt, because advertising plays such a tremendous part in the merchandising world; and the selling of city advantages, in sites, climate and transportation, appears to be the normal function of many city and town organizations. In a careful analysis of the advertising methods of hundreds of towns and cities, it is fairly evident that advertising has not been a serious study, for in many instances time-worn schemes which have long since served their purposes and some which were never provocative of results, are still in existence. It would be a bold person who tried to answer the questions as to what extent city advertising is economically justified. However, certain inferences may with safety be drawn from the study of the growth of American cities and from the advertising of these same centers. The first part of this paper discusses the growth of the cities of the United States during the last ten years, and incidentally the advertising of these: and the second part is a study of the advertising of the cities, particularly the most extensive advertisers, and incidentally their growths.

CITIES OF GREAT INCREASE: 1910 TO 1920

One hundred cities in the United States had a growth between the years of 1910 and 1920 of 37.5 per cent. or over; twenty-five of these had an increase of over 100 per cent. in this ten-year period; and two of the latter had increases in excess of 1,000 per cent. The greater part of these cities attained their growths because of a single cause; automobile manufacturing, automobile accessories, suburbs, resorts, oil and gas, and so on. The second one hundred cities show no such singleness of cause of growth and the study of the reasons for their increases becomes indefinite; for this reason only the first one hundred are considered here.

A—Automobile centers: Thirteen of the hundred cities owe their increases to the manufacturing of automobiles and to the

production of automobile accessories. The average growth of the thirteen centers was 230.4 per cent. and the individual cities have a range in increase from 1,266 per cent. to 40 per cent. This is the greatest average growth shown by any group of cities in this study. Among the cities in this group will be found Hamtramck, Michigan (increase of 1,266 per cent.), Highland Park, Michigan (increase of 1,028 per cent.), Akron, Ohio (increase of 201 per cent.), Flint, Michigan (increase of 137.6 per cent.) and Detroit, Michigan (increase of 113.3 per cent.).

The value of the product per man in the automobile industries has been as a rule much greater than is the case in the normal run of manufacturing establishments. In 1919 the per capita value in the automobile industry in the city of Detroit was $6,285, while the average in all industries was $3,454. A part of this higher value has been due to wages which has made the automobile cities the Mecca of all workers in wood and iron. It is evident that the country has not reached the saturation point of automobiles, and until such time as this condition is attained, this group of cities will probably go on increasing in ratios corresponding to those recorded during the last ten years. But with Detroit building in 1920 1,250,000 cars, or one car for every nine seconds of the working day; with the Ford Company reaching 100,000 cars a month and a record of 4,688 cars in a single day, it would appear as if the saturation point could not be long delayed. The total gain in population in Michigan during the last decade was 857,049, and 84 per cent. of this gain occurred in the four automobile cities of Detroit, Flint, Lansing and Pontiac.

Cities of this group have received enough advertising from their products and from the favorable conditions of the labor market to enable the city authorities to dispense with extensive advertising of an informational nature. The truth in the case of automobile manufacturing is so impressive that the daily papers and the popular magazines have reported the activities of these centers and have kept them before the public. In general it is safe to say that these are cities of no particular form of active advertising. They may publish a trade board journal. For example, the *Detroiter*, the magazine of that city's Board of Commerce, records the daily and yearly activities of the automobile industries without any attempt at an elaboration. These facts are interesting enough to be quoted extensively by the press, eloquent enough to be appealing and persuasive enough to actually attract not only the manufacturer of automobiles and automobile accessories but to move sufficient labor and capital to these centers to guarantee their continuation and growth.

B—Oil and Gas centers: The second group of cities of which there are eight in the hundred are oil and gas centers. These cities have an average increase in population between 1910 and 1920 of 170.2 per cent. This group might easily be rated with the automobile cities, since the great demand for oil and gas is a direct resultant of the increase of the motor car. Some of the cities of this group are Wichita Falls, Texas (with an increase of 388.8 per cent.), Tulsa, Oklahoma (increase of 296.4 per cent.), Clarksburg, West Virginia (increase of 202.9 per cent.), Beaumont, Texas (increase of 95.8 per cent.) and Fresno, California (increase of 81.1 per cent.).

The centers of oil-producing areas show every sign of being mushroom cities and this is emphasized by the trade organizations in these centers in their vigorous insistence that the cities are stable commercial or agricultural centers, not dependent on oil. Wichita Falls with a population of about 10,000 in January, 1918, ended the year with a population of about 40,000. In July of that year a wild-cat test near Burkburnett, 14 miles north of Wichita Falls, brought in oil; and the tide of investors and prospectors set in toward that city. The advertising of this group of cities is of two kinds—the wild-cat advertising of oil prospectuses, which is the real drawing card of these centers and which accounts largely for their increases and the advertising of the city itself. The wild-cat advertising from the standpoint of the towns involved is free advertising, similar in nature to that of the automobile cities. The second type of advertising of this group is the usual city advertising carried on by the local trade chamber. The tendency in this latter type is to stabilitate the increases created by the wild-cat advertising and to turn the attention of the prospect away from oil—tacitly assuming in the process that the oil trade is transient. Thus the Wichita Falls Chamber of Commerce:

> Wichita Falls is the supply and distribution center for a dozen great oil fields—and yet Wichita Falls is not an "oil town." It is a modern city of commercial and industrial importance, with big manufacturing, retail and jobbing interests that reach out into a trade territory with a radius of 100 miles.
>
> While it is true that the discovery of oil brought a great influx of wealth to Wichita Falls, oil did not create the Wichita Mill and Elevator Company, the Wichita Motors Company, or any other of the 45 prosperous manufacturing plants. It is not oil that is responsible for a manufacturing and jobbing business in Wichita Falls of approximately $40,000,000 per annum.

C—Suburbs: This group of cities owe their increase to suburban situations and represent the outpushed surplus population of crowded city sites. Some of the cities of this group are Cicero, Illinois (with an increase of 209.1 per cent.), East Cleveland, Ohio

(increase of 197.3 per cent.), Lakewood, Ohio (increase of 174.9 per cent.), West New York, New Jersey (increase of 120.7 per cent.) and Irvington, New Jersey (increase of 114.5 per cent.). Altogether in this group there are ten cities of the hundred cities of greatest increases, and the average increase for this group is 114.8 per cent.

In all cities of a population of 200,000 or over the suburban areas increased at a greater rate during the last ten-year period than did the centers themselves. The movement from rural to urban districts which has persisted for a number of years became accelerated during the 1910-1920 period, and much of this occurred doubtless during the last five years of this period. These suburban increases were more noteworthy than the census figures show, for many cities have increased their bounds to include the neighboring people and are thus included in the city population rather than in a suburban population. Detroit's jump from thirteenth place in 1910 to fourth place among the cities of the United States in 1920 was aided by an actual increase in area; and another increase may be realized if Highland Park and Hamtramck, islands within the corporate bound of Detroit, yield to the blandishments of the ambitious city. Norwalk, Connecticut (with an increase of 299 per cent.), Bethlehem, Pennsylvania (increase 292.2 per cent.), and Los Angeles, California (increase of 80.7 per cent.), are other examples of increases due in part to enlarging the area. The true city of the suburban type may be illustrated by East Cleveland, Ohio, and Lakewood, Ohio, whose increases are the overflow from Cleveland (increase of 42.1 per cent.). Most of these cities are much less well known than the centers of production of which they are a part. Rarely do they have boards of trade, since they are purely residential sections, and advertising does not enter into their plans. Now and then a suburban site, Cicero, Illinois, for example, builds itself at the expense of the host city by advertising competitive tax rates and attempting to operate on a lower tax basis. Cicero decreased in population between the years 1900 and 1910 by 10.7 per cent.; but between the years 1910 and 1920 the bait of a low tax rate on industrial establishments attracted a few concerns from Chicago with the result that the city stands at the head of the suburban group in amount of increase in 1920. This type of advertising, under the present conditions at least, must be classified as wild-cat advertising.

D—Steel cities: The next group is the steel and steel products cities. Eighteen of these are found in the first one hundred cities and the average increase was 78.3 per cent. Here are found Bethlehem, Pennsylvania (with an increase of 292.3 per cent.), Gary,

Indiana (increase of 229.6 per cent.), Warren, Ohio (increase of 144.1 per cent.), and Canton, Ohio (increase of 73.4 per cent.); further down in the list are the larger cities of Toledo, Ohio, Cleveland, Ohio, Bridgeport, Connecticut, and Erie, Pennsylvania. Bethlehem is rated with an increase of 292.3 per cent., but subtracting the increase due to accession of territory, its true increase was about 53 per cent.

It is an expectable thing to find that this industry, enlarging its plants as it did under the conditions which prevailed during the period from 1914 to 1919, should be the means of increasing the size of the localities where they are best developed; but the abnormality of the times hardly makes any conclusions from these increases possible or safe. It is interesting to note, however, that the cities of this group do not fall into the class of advertising cities. They do have trade organizations which set forth modestly the conditions and advantages of the particular site, but this material is generally distributed by exchange with other similar organizations rather than widely circulated as advertising matter.

E—Resorts: The city groups so far mentioned do not follow any regular and persistent advertising plan. Some of them write that they do not advertise at all, as they do not need to do so. Seven of the cities in the list of one hundred are thorough advertisers—these are the resort cities. These cities have an average increase of 72.7 per cent. and they include Long Beach, California (with an increase of 212.2 per cent.), Jacksonville, Florida (increase of 58.7 per cent.), Asheville, North Carolina (increase of 51.9 per cent.), Pasadena, California (increase of 49.7 per cent.), and Miami, Florida (increase of 35.1 per cent.). These increases are more nearly normal growths for this type of city than is the case of any of the previous groups, and these increases have been maintained in resort cities over a number of years. There are so many resorts of various kinds in the United States and all of them are such prolific advertisers that there arises the question why only seven have registered a large increase in population. In an analysis of the resorts of this group, there appears to be in all cases a combination of resort and business which makes the attraction; and this combination, being somewhat different in each case of the seven, places these cities in another group of sporadic types with a common factor in resorts.

The majority of resorts advertise for a transient trade, and thus they do not appear in the category of cities with permanent increases. This is shown by Atlantic City, New Jersey, which increased by about 10 per cent. only in the decade; but this 10 per cent. probably means a great increase in the number of visitors

to the resort, since the 10 per cent. represents the number of additional persons, permanents, that are needed to care for the transients.

F—Other Cities: This accounts for fifty-six of the hundred cities of greatest increases in population. Of the forty-four remaining, there are ten cotton and cotton products cities, nine food products cities, eight lumber and lumber products cities, and seventeen scattered cases. A small percentage of these advertise extensively. The most noteworthy cases are Phoenix, Arizona (with an increase of 160.9 per cent.), San Diego, California (increase of 89.4 per cent.), and Los Angeles, California (increase of 80.7 per cent.). Without going further in an analysis of these city groups, there is enough evidence to make the assertion that the majority of cities of maximum growth during the last ten-year period did not attain their numbers through any consistent internal organized advertising. They were the product of the times, pure and simple.

City Advertising

Advertising has in so many instances been the result of mimicry and imitation that there is a possibility of classifying into types much of the advertising now being indulged in by cities. The number of cases where the city has departed from certain established types of advertising is not many. The tendency to do this is more marked to-day than ever before. It is strange that in these days when business is being tried for efficiency the time-worn schemes of city advertising have never been investigated. Some of these cost little or no money, and it is probably for this reason that no great concern has been felt for them. Three very common types are mentioned here

A—The City Slogan: The most widespread feature of city advertising, appearing more commonly than any other one type, is the city slogan. These phrases, which are intended as catch-words, are in 95 per cent. of the cases valuable only as an indication of the city fathers' aspirations for their child. In a large number of instances they encompass so much as to make them specifically unattainable; and in most cases they degenerate into platitudes that border upon utter foolishness. As a rule they are commonplace and ineffective because of these reasons

"The City with a Personality"—Tulsa, Oklahoma

"Where to-day's dream is to morrow's opportunity"—Wichita Falls, Texas

"The City of Opportunity"—Gary, Indiana

"The City of Diversified Interests"—Canton, Ohio

"Where enterprise was invented"—Lansing, Michigan

"The Place with the Power and the Push"—Columbus, Georgia.

The following statment appeared in a recent number of the Providence *Journal:*

> The Lions Club, an organization in Wilmington, Delaware, offered a prize of fifty dollars not long ago for the best local "slogan." The announcement is now made that two young men of the city both entered the winning phrase in competition, and so presumably the prize was divided between them.
>
> Their choice is interesting "Wilmington—the first city of the first state" It might be thought that while there is no doubt of Wilmington's municipal primacy in Delaware, as the next largest community has a population of only five thousand, the reference to "the first state" is a mere baseless boast . . . .

Now and then a slogan is invented that sticks to a city and becomes, even in boastful language, a constituent part of the city's advertising. In general, however, this rule may be applied, namely, that it is not so much what a city decided to say of itself that counts in this matter but what it can induce outsiders to say of it. The test then of a successful slogan is its adoption without, not within, the confines of a city, and to this test very few slogans measure.

B—The Trade Circle: A second type of advertising indulged in by cities is a map showing the trading district. Frequently this is printed by drawing around the city a circle of varying radii—80, 100 or 125 miles, and the inference is assumed that the population within the area has trade connections with the center. In most cases this is vicious advertising.

Wichita Falls, Texas, publishes such a circle with a hundred mile radius showing the railroad lines converging toward that city, and the map is labelled "Wichita Falls Trade Territory." Wichita Falls has a population of 40,000; the 100-mile circle just misses Fort Worth, population of 106,482, on the southeast; Oklahoma City, population of 91,295, on the northeast; and is within fifteen miles of Dallas, population of 158,976. This is the common fault of such types of advertising; and in every case examined there has been neglected the influence of adjacent areas, with a trade in most cases of greater importance, the possibilities of transportation, and the normal flow of trade.

The *Providence Magazine,* Rhode Island, published by the Chamber of Commerce of that city, publishes in every issue of the magazine a map of the northeastern section of the United States. Around Providence, New York and Philadelphia are drawn circles with radii of 80 miles. The Providence area is marked "Third most populous 80 miles radius in the western hemisphere; population 4,188,651;" and the order of importance of these areas is given thus: New York, Philadelphia, Providence, Boston, Chicago

and Baltimore. The 80-mile radius around Providence encompasses Middletown, Waterbury and Hartford, in Connecticut: Springfield, Holyoke, Lowell, Lynn, Salem, Gloucester and Lawrence in Massachusetts; and Nashua in New Hampshire—and not one of these cities is connected directly with Providence. As a matter of fact any one of twenty-five cities lying between Trenton, New Jersey, and New Haven, Connecticut, would with an 80-mile radius surround a population larger than that given for Providence. It is, however, not so much a question of veracity concerning figures with which we have to deal, but an inference concerning trade movements, and in this particular the Providence "Trade Circle" is highly mendacious.

C—The Bill Board: A third type of advertising indulged in by cities is the bill board, located at some favorable site along the automobile highway or railroad. In general this is more modest advertising than either of the other two types, and it has the advantage of gaining a larger audience than the others. No estimate of the value of these can be made from any records or impressions which city organizations have on file. A rather widespread lack of knowledge concerning them was apparent. Obviously many of them have outlived their usefulness, as the data on them are obsolete; while the general state of unrepair of some of them rather indicates that they are not rated high in those communities.

Advertising may be competitive or it may be informational; advertising of a competitive nature is not economically justified; it has a selfish aim and it is a burden to the ultimate consumer. Advertising of an informative character is in the line of education, and the consumer is willing to pay for this. Most city advertising is too competitive to be ranked high in advertising science. The location of manufacturing concerns is determined by many factors, the least of which during the last decade, at least so far as large establishments are concerned, appears to have been the embellished advertising of the various cities. Cities which are large advertisers have not always increased as much as the average increase of urban communities in the United States (28 per cent.) for the ten-year period. Denver (20.2 per cent.), Portland, Maine (18.3 per cent.), Portland, Oregon (24.6 per cent.), San Francisco (21.5 per cent.), all fell short. Seattle, one of the most consistent advertisers and incidentally an advertiser on rather a higher plane than is usual, has increased but little more than the average city increase for the entire United States (33 per cent). It should be noted, however, that this city's widespread advertising campaign is of too recent date to be effectively measured in the returns of the last census.

City growth in any country should have a normal progress. It should avoid the utter despair and degeneracy portrayed by Wells in his "citylessness" Europe, but also it should avoid the profligacy of "citymoreness."

In a new country where the physical advantages for development are eminent, but there is lacking a certain density of population, it is a legitimate process to attract settlers by rebating transportation rates; by offering free lands and implements and by establishing a preferential tax rate; but in a land so overburdened with cities as the United States is threatening to be, there is something inconsistent between the struggle of cities to increase by large percentages and the ideal of the land as a self-sustaining nation.

It has been said that the statement that people are leaving the country more and more is to put a misleading emphasis on a normal fact in the modern growth of population. It is further explained that the city increase is the normal result of country growth, that country populations should be thinner than city populations, and that cities should take the larger part of the natural increase of the country populations; this is the explanation of what is happening. Notwithstanding, the percentage of urban dwellers has constantly increased, from 35.4 per cent. in 1890, 40 per cent. in 1900, 45.8 per cent. in 1910 to 51.4 per cent. in 1920. Just what the right ratio between urban and rural communities should be is problematical, but there appears to be considerable concern over the fact that in 1920 for the first time the percentage of urban population passed the half-way mark of the total population. The increase of urban population from 1910 to 1920 was 28 per cent.; and of rural 3 per cent. On the other hand the beginnings of stress for food indicate that the 3 per cent. are not adequate to care for the increase of 28 per cent.: or that 48.6 per cent. rural population is hardly a sufficient number to give the country a surplus. While the numbers of rural dwellers increased, the number of workers in rural communities actually decreased by something like 100,000 and this with 14,000,000 more mouths to feed. City advertising must take account of this fact in the near future. Is it safe to attract from rural communities? Is it a legitimate aim in city advertising to outclass in numbers some other rival community? What is the function of such advertising? No community has attempted to answer this, but until some vision of these things is before the advertiser, city advertising will be wasteful and inefficient.

METHUSELAH OF THE MISSISSIPPI

By Dr. R. E. COKER

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THE Father of Waters, with all its mysteries, presents no individual prototype of Methuselah, but it harbors in its bosom a species of fish that is even more ancient with reference to other kinds of fish than was Methuselah with reference to his youngest grandchild of the *n*th generation. The paddlefish, often called spoon-bill cat (sometimes, I dare to say, termed *Polyodon spathula*), is our single representative of an order of shark-mouthed fishes which is believed to date back to a very early period in the evolution of the finny tribes of fresh waters and the sea. There is one other living representative of the order, but it is found only in some rivers of China, being dignified with the scientific name of *Psephurus gladius;* the popular Chinese name we have forgotten, if we ever knew. Some seventy-five million years ago America boasted another representative of the family of Polyodontidæ, but we know it now only through the fossils found in eocene formations in Wyoming;—and not many of us know it even there! The two lone survivors of an ancient family, Polyodon and Psephurus, are far removed from each other and presumably have not had even a speaking acquaintance within a million years.

The paddlefish might be a good deal more lonesome if it did not have a few near contemporaries dwelling alongside. Closely associated with our hero in the society of oldest inhabitants of fresh waters are the sturgeon, gar-pike and bowfin. Could we steal in upon a clandestine meeting of that dignified society it would be interesting to compare the distinguished members. Observe first the paddlefish with its mostly naked skin and (using an x-ray machine) its cartilaginous (not bony) skeleton. There, too, are the sturgeons who also have a cartilaginous skeleton, but they wear a knightly armor of hard bony plates or scutes; besides they boast a magnificent "beard" of four barbels—a mustache it might better be called, since the barbels are in front of the mouth—while the paddlefish has only the feeble adornment of two barbels and these so small that it takes an expert to find them. Next come the wicked old garpikes—to say nothing of two strange fishes of Africa which have been condemned without a hearing to be called Polypterus

and Calamichthys. These wear an even more complete coat of mail than do the sturgeons, but their skeleton is somewhat new-fashioned in respect of being largely bone. Finally we see the bowfin, grindle, dogfish, mudfish, lawyer—or whatever you choose to call him; he, too, has a bony skeleton, and, while not strongly mailed, is covered with scales. He might be thought to be almost modern, except for—but that's another story which has nothing to do with the paddlefish. It is noteworthy that three of the groups of the ancients—the sturgeons and garpikes, as well as the paddlefish—have either prolonged snouts or bills, while all the regular every-day sort of fish are almost invariably short-nosed, as everybody knows.

Lest it be thought that in singling out the paddlefish as a representative of antiquity we do an injustice to the sturgeon, let it be said now that, conceding to the "hackle-back" all the honor due to abundant years, we can not venerate him as we do the paddlefish. Jared attained an age but a year or two less than Methuselah; but does he rival Methuselah in our esteem? By the unanimous verdict of succeeding generations, Jared's name is confined in the archives of history, while that of Methuselah remains a household word, as familiar as those of George Washington or of Abraham Lincoln. How, then, could the sturgeon dispute the proud place of Polyodon in the halls of fish fame?

What are the more striking external features of the paddlefish? Behind the long spatulate bill we observe a very wide mouth, sharklike in position, being entirely on the under side of the body, but relatively as cavernous as that of a hippopotamus; there are spiracles open above, as in sharks; there are no spines in the broad shoulder fins; the body is scaleless, except for isolated vestigial scales embedded in the soft skin and a continuous series of small rhombic plates on the upper part of the tail; and the tail, by the way, is heterocercal. This last named feature is important. Do not forget the heterocercal tail! Heterocercal, it may be explained, is merely a hard name for the kind of tail which we associate with sharks, that is, one with the vertebral column extending into its upper part, giving a rakish, saucy effect. But the snout, after all, is the principal thing, being one third of the total length in fish of small size and about one fourth of the total length in large fish 5 or 6 feet long. It is rigid in the middle line, but has thinner and more flexible margins. As we shall see, it is so covered with sense organs and full of nerves that it must be capable of serving most delicate tactile functions.

Another external feature of the paddlefish, which is very sug-

gestive of the sharks and their relatives, is the color contrast between the upper and lower sides. The back and the upper parts of sides have steel or slate-like hue, while the underparts are glistening milk white. The fins of the most mature individuals may be slate-like or dashed with a delicate tinge of salmon pink. A peculiar reddish tint has sometimes been observed over the bodies of fish that have recently spawned.

About 6 feet would appear to be the maximum length attained by our species, though its Chinese relative is said to attain a length of 20 feet. Paddlefish taken in the Mississippi and its tributaries are usually between 2 and 4 feet long. The largest known example, weighing 163 pounds, was taken in Lake Manitu, Ind.

Barring exceptional records, the paddlefish has been found only in the Mississippi River and its principal tributaries. It is rarely found in lakes or rivers of a depth less than 10 feet, and may, therefore, be quite unknown to persons living a short distance from one of the principal rivers of the Mississippi Basin. Thus, when an individual example was caught a few years ago in the Des Moines River near Ottumwa, it astonished the local fishermen who had seen nothing like it before although they lived but 70 miles from the Mississippi River where paddlefish were as well known as catfish. Strange to say in this connection, one of the largest paddlefish of record was taken as far inland as Lake Chautauqua, N. Y., in 1890, the fish having a length of 6 ft. 2 in., a girth of 4 ft. and a weight of 123½ pounds.

Rare as it may be in the smaller tributaries, the paddlefish has real commercial importance and wide distribution in the larger streams of the Mississippi Basin and in neighboring deep lakes connected with the river. In Lake Washington, Miss., as many as 150 barrels of Polyodon have been taken in one haul of a seine two miles in length, while, a thousand miles to the north, in Lake Pepin, an expansion of the Mississippi between Minnesota and Wisconsin, it was (until very recently) possible for the big seine to bring in a thousand or fifteen hundred pounds of paddlefish in a single haul.

In several southern lakes, paddlefish and other species are taken with a great seine, from one to two miles long and from 15 to 30 feet deep. The seine is wound on a large reel carried on a heavy barge, which is towed around a circular area, a mile or more in circumference, while the seine is reeled out. The barge being then anchored, the crew of a dozen men wind in the seine by walking up the spokes of the wheels at each end of the reel, as on a ladder, so that the reel is made to revolve. As the seine is thus gradually rewound on the reel, the fish in the circle enclosed by the portion

Photo by R. E. Coker

ONE THOUSAND POUNDS OF PADDLEFISH, BUFFALO FISH AND CARP. LAKE PEPIN, 1913

of the seine in the water become confined to a narrower and narrower space, while they dart wildly about seeking means of escape. It takes about 4 hours to complete the operation, which may bring in a hundred valuable paddlefish.

In Lake Pepin, the seine, which is nearly a mile in length, is hauled ashore by long lines passed over stationary winches located on the banks and turned by gas-engine power. While in northern waters the paddlefish has no well-developed roe to enter into the commercial appraisal of the fish, nevertheless it has, for some years, been accounted one of the most valuable species to catch on account of the value of its meat. The result of the intensive fisheries practiced in various parts of the country has been, of course, to bring about a rapid depletion of the supply of this fish.

As regards the larger rivers, seines can be employed only along the shores and in outlying waters; where current prevails, the fishermen resort to the use of fyke nets (hoop nets) or of trammel nets. At Keokuk, Iowa, fishermen were observed to take paddlefish by the use of trammel nets set at night in the very swift water below the dam. Here the operations were attended with some little danger, since the greatest care was required to prevent the extremely swift current from throwing the boat against old piles and other partly or entirely submerged relics of the time of construction of the great dam.

I recall vividly my own experience in a small boat fishing close up in the tail race below the power house of the Mississippi River Power Co. The hours were wee and small, for we had gone out at 12 midnight in accordance with the dictum of the few fishermen that cared for that particular kind of fishing. The waters, which had fallen 30 feet through 13 big turbines and shot out through the submerged chambers of the power house into the tail race paralleling the house, flowed down stream with great force and turbulence. At the same time, the surface water rolled outward through the remnant of an old cofferdam, represented by scattered piling, some partly exposed and some altogether submerged. The night was calm elsewhere, but not so here. In the rushing, swirling, waters, the management of the boat alone might have seemed a sufficient task; but, with the drag of a long trammel net being paid out over the stern, when the conflicting currents often chose to take the net one way and the boat another, the energies and resources of the fishermen were severely taxed. Piles looming suddenly in the darkness, boiling, slopping waters everywhere, suspicious swirls fixed in location and indicating submerged dangers, excited commands to the oarsman and from the oarsman all combined to make the experience one of thrills more delightful in the retrospect than in the actuality. Alert eyes, quick action, and strenuous exertion, not to mention good "sea-legs" and "seamanship," saved the day, or rather saved the night, during the paying out of the trammel. If the trammel net was not entangled with the piling, its taking in and the removal of the paddlefish was relatively simple when the boat had drifted well below the zone of danger. But the drifting was not always unchecked; the net might become entangled on a pile in the strong current -and then there was some joy in life while extricating as much of the net as the piling chose to release. For well-considered reasons, I did not personally pursue the fishing operations throughout the period of fishery—several hours. However, after a brief experience, I had learned something of the midnight habits of the paddlefish in this region, and I came to suspect that the broken-snout paddlefish, which were so frequently encountered in the waters below the dam, were not unacquainted with the piling. If, in that rushing current, these seemingly stupid and dim-visioned fish thrust their long snouts between two piles with the same bravado that they rushed into the trammel net, I think I know what would happen.

What happens to the paddlefish after it is captured is less exciting. In dressing the paddlefish the heads and fins may be dis-

Photo by A D Howard

A CATCH OF PADDLEFISH AT HYAMS CUT, OFF HYAMS LA

carded or saved and boiled for the oil they yield. The roe, which weighs from two to fifteen pounds in a single fish, is put on a coarse wire sieve and rubbed by hand across the wires until the eggs are separated from their membranes and drop into a bucket beneath. The eggs in this form, or caviar, when mixed with special salt, are ready for shipment, although they must undergo still further preparation before they are ready for the table.

Commercially the paddlefish is highly esteemed by fishermen. The flesh is good and, though it has not become known under its own name, it is shipped to the larger markets there to be dried, smoked, and masqueraded as "dried sturgeon" or as "boneless cat." In Lake Pepin in 1913 they would not even call a paddlefish in the seine by its proper name or by its colloquial designations of "spoonbill cat." They patly designated it *shovel-nose sturgeon* and shipped it to Chicago where, at a time of low prices for fish, it brought 12½ cents per pound while buffalofish and carp brought only 3½ cents.

The roe is much more valuable than the meat, since it is used, like sturgeon roe, to make caviar. While, strictly speaking, caviar is the roe of the sturgeon of Europe or America, prepared in a certain way, nevertheless *erzatz* caviar is made from the eggs of

several species of fish, including the whitefish of the Great Lakes. Under regulations formulated to enforce the Pure Food and Drug Act, other caviar than that made from sturgeon roe must be designated when sold, by the name of the fish from which it is made, as "whitefish caviar." The roe of the paddlefish is, however, so nearly like that of the sturgeon that paddlefish caviar, it would seem, is hardly to be designated as an imitation. In 1917, at Keokuk, Iowa, sturgeon roe was bringing $2.95 per pound and the meat 16 cents per pound. Paddlefish roe probably brought approximately the same price, and, as the roe of a large paddlefish may weigh 15 pounds or more, it is evident that an individual fish in proper condition represents a very valuable catch.

But how long will it last? In 1894 the paddlefish was not esteemed; but the catch in the Mississippi River and some of its tributaries amounted to more than 1,000,000 pounds, valued at about $21,000. It was about 1896, apparently, that fishermen along the lower part of the Mississippi River began to utilize the roe for making caviar, and in 1899 the catch had increased to 2,473,000 pounds, valued at $55,514. The rated value is proof that the fish was little appreciated; nevertheless its early decline in abundance is evidenced by the fact that the catch of paddlefish reported by the Bureau of the Census for 1908 amounted to one and one half million pounds, valued at $49,000: the unit value was going up some. Later the fish began to bring a price, but we have no recent general statistics to show the present trend.

The decline of the paddlefish in Lake Pepin is notable. In 1903 and 1904 it was one of the most abundant fish in the lake throughout the summer. Big catches were regularly made. Subsequent statistical canvasses conducted by the U. S. Bureau of Fisheries showed a catch of hardly 9,000 pounds in 1914 and less than 3,000 pounds in 1917. Visiting the lake in September, 1921, I was told that the first paddlefish of the season, 4 in all, had been taken the preceding day. I witnessed a catch of 20 examples, 30 inches to 4 feet long, which were greeted with enthusiasm by the fisherman as representing a big find. In 1913, I had observed a larger haul which was regarded as in the order of the day. The barrier across the river at Keokuk has perhaps had something to do with the rapid disappearance of the paddlefish from Lake Pepin relatively to its general decline in all waters.

II

The paddlefish is remarkable not only for its bizarre appearance, its primitive structure, and its isolation from any relatives,

but also for its feeding habits. One might suppose that a species which had survived for such a long period would be found to be peculiarly fitted to take care of itself in conflict with associated species; that like the sharks of the sea and the garpikes and bowfin of fresh waters, it would be extremely predaceous, if not actually pugnacious; but, like Methuselah in his last years, or last centuries, perhaps, the paddlefish is extremely peaceful in disposition and addicted to a diet of the simplest character. It may have attained its second childhood, or it may never have left its first childhood, as regards the matter of feeding. The young of all of our common fishes, having tiny mouths, must feed upon the smallest food articles. They are practically all, therefore, "plankton feeders" in early infancy; that is to say, they consume the minute floating plants and animals or organic materials which comprise what is called plankton. As a general rule plankton is to infantile fish what the bottle is to infantile man. Whether or not Methuselah found it necessary to revert to the bottle after attaining an age of seven or eight hundred years, we find the paddlefish of all sizes and ages subsisting upon the sort of food which a black bass would be ashamed to be caught eating at an age of six or seven months.

"The most remarkable in many ways of our American fresh-water fishes," say Professor S. A. Forbes, a veteran student of the fishes of interior waters, "is the Polyodon or paddlefish, and in nothing is it more peculiar than in the fact that, although it is one of our largest fishes, reaching a maximum length of six feet and a weight of a hundred and sixty pounds, it is essentially a plankton-eater, feeding largely, and sometimes almost wholly, on the smallest aquatic animals and plants for the appropriation of which it has, in its gill-rakers, a straining apparatus scarcely less effective than that of the whalebone whale. To strain out the plankton, it holds its enormous but weak-jawed mouth wide open as it swims about, permitting the water to flow through its very wide gill slits, getting thus not only the smallest animals and plants, but many insect larvæ also of kinds abundant on the open bottom in comparatively shallow water. It is indeed a living, fine-meshed, water-net."

It is said that one may often scrape more than a double handful of Entomostraca (small water "bugs") from the mouth of a paddlefish freshly brought up by the seine.

Scientists, as well as others, sometimes have a special fondness for proving the fitness of things, or establishing a positive relation between structure and function. Some have thought that the paddle of the paddlefish was used as a sort of shovel to stir up the mud on the bottom ahead of the fish, after which the gill apparatus

Photo by A D Howard

PART OF CATCH OF PADDLEFISH HYAMS CUT, OFF HYAMS, LA

would effect a separation of the nutritive organic matter from the mud. It does not appear that it would be physically practicable for the straining apparatus to accomplish this result, inasmuch as the mud would be composed of as fine particles as the food matter. It is also a reasonable presumption that, if the paddle were used in this way, its edges would be found considerably abraded from frequent rubbing against mud and débris on the bottom.

If the paddlefish fed habitually by stirring up the sediment upon the bottom we might expect to find an appreciable quantity of silt in the stomach contents; but observers say this is not the case. The content of the stomach of the paddlefish is usually, indeed, a very clean collection of the minute animals or plants such as occur swimming or floating in the water more abundantly than amidst the bottom materials.

It is much more likely that the paddle is a tactile organ serving to guide the fish into areas of water where its normal food is found in the greatest abundance. Feeding as it does upon very small particles of floating food, the paddlefish would seem to require a sort of antenna by which to feel its way into the thickest swarms of food, and the long flat paddle, which is "fairly paved

with sense organs," seems well adapted to serve the function of a "feeler." One observer found occasional examples of paddlefish gorged with larvæ of mayflies, those interesting insects which spend a year or two of immaturity on the bottom of a river to emerge finally for but a single day or two of glorious aviation; but in every such case recorded, the adult mayflies appeared in vast numbers in the evening of the same day. It may, therefore, be presumed that the paddlefish merely captured the larvæ in their journey from the bottom to the surface of the water preparatory to the emergence which would so closely precede the end of the journey of life. Some have recently been found gorged with aquatic insect larvæ of the only species that roams freely in the water making its base neither at the bottom nor at the surface (Corethra).

Perhaps one ground for the old supposition that paddlefish feed upon the bottom is the fact that they are rarely found except where the water is deep, and the bottom in such places in interior waters is usually muddy; but on the other hand, it is observed that those taken in seining operations, when they become gilled in the seine, are always found near the cork line. As a matter of fact, the paddlefish is probably nocturnal in its feeding habits, and retires to the darkness of the deeper water during the day, not for feeding, but for protection and repose. We have previously referred to the fact that operations with trammel nets at Keokuk, Iowa, were conducted at the surface at night. The eyesight of the paddlefish is very deficient and, as it leads a life that is by no means sedentary, it must have some other acute sense organs for its guidance, and this apparently is the function of the paddle.

Concerning the extent and seasons of its migrations we have virtually no information. It is known that it roves about the lakes in schools and that it disappears from observation for brief periods, but there is lacking evidence that it entirely leaves any locality in which it is commonly found at some season.

It is remarkable, indeed, that this fish should have maintained itself through countless years, in competition not only with other species of like size and more "suvigrous" disposition but also with the smaller fish of nearly all species, which take the same sort of food, and its survival is all the more an occasion for wonder since it is apparently gifted neither with keen vision nor with such a measure of intellectual activity as we could term "good fish sense." Observe its behavior in a tank; it repeatedly swims against the ends or sides of the tank, as if it could not see beyond the end of its

nose. When, in the open water, the fish strikes a net it often stops, pushes weakly forward a time or two and then gives up, turning on its back and floating along the cork line. It allows itself to be removed by hand almost without a struggle. Dr. Hussakof, formerly of the American Museum of Natural History, has well described its behavior under such circumstances:

"Its sense of sight is poorly developed, as indeed one might infer from its small, beady, black eyes. If its 'nose' is caught in the seine it makes only feeble efforts to free itself, and usually fails in doing so. The contrast between the clumsiness of the spoonbill and the alertness of an active fish is strikingly brought out if a garpike is taken in the same haul; for the gar makes tremendous efforts to escape and, unless rendered unconscious by a blow with a mallet, will flash through the seine as if it were gauze. Leaning over the side of the boat, near the corkline of the seine, one may seize a five-foot paddlefish by the 'nose' or the tail and haul it into the boat; the only resistance is that of weight. The fish has absolutely no sport value."

As resistant as the paddlefish may be to the changes of time and the physical injuries acquired in the open water, it does not stand handling or close confinement. Attempts to convey paddlefish in a boat on the Mississippi River, in a large stock watering tank which was carefully tended while traveling a distance of about 100 miles, usually met with failure. Few paddlefish survived the period of eight or ten hours consumed by the journey. Attempts to retain them in wire-meshed enclosures 20 feet square in lakes which were their natural habitats have also failed, though the fish have been successfully kept by fencing off a small arm of a bayou. On one occasion some paddlefish were successfully transferred in a fish car from the Mississippi River to the Portland, Oregon, exposition. They lived during the journey but all died during a brief delay in the yards before the fish could be delivered to the aquarium of the exposition.

After many trials a considerable number of paddlefish, mostly of smaller sizes, were placed in a reservoir at the U. S. Fisheries Biological Station at Fairport, Iowa. The reservoir is just a little less than an acre in surface area and about 16 ft. deep. Here the paddlefish have apparently found conditions to their purpose, for nearly all of them have lived for about 5 years and gained considerably in length.

There was observed a peculiarity in the behavior of the paddlefish in a tank in that they soon turned upside down, when they

would remain motionless and appear to be dying. If they were righted with the hand, they would then swim about as if entirely revived, but after a time would turn over again. Why? This is not the only puzzle of the paddlefish. In one experiment some fish were conveyed successfully after tying a cork on the top of the snout in such a way as to compel the fish to remain right side up. An investigator, by the way, found that a paddlefish tethered to an empty gallon jug by a line 5 or 6 feet long and set free in a lake could be kept in good condition and recovered at will. The seeming contentment when moored to a jug would seem almost human but for the fact that the jug is reported to have been empty.

The paddlefish may not be gifted with intelligence of a high order, but at least it can keep a great secret; that is, as to when, where and how it breeds. We know the eggs, for the large roe with eggs sometimes seemingly almost ripe, is a staple article of commerce, but where and when the eggs are laid, if they are laid, and how they are cared for, if they are cared for, and where and how the new-born young live and grow—the fishermen and the scientists, in spite of repeated investigations, are still guessing. On only one occasion have examples less than 6 inches in length been taken, and these were gathered by an indefatigable searcher who seined the bars of the Mississippi and Ohio Rivers and neighboring sloughs and lakes in the vicinity of Cairo, Ill., throughout the period of an entire year. Where are the developing eggs and where are the new-born and the infants less than 4 inches in length? This is Methuselah's great secret. Problems seemingly much more difficult than the spawning of the paddlefish have been solved with less effort—but the paddlefish still cherishes its own mystery. If you

wish an easy task, find out where Capt. Kidd buried his treasures or where the paddlefish hides its young.

This much, at least, the paddlefish lets us know: that there are no evident external differences between males and females; that paddlefish of some 15 pounds weight may be apparently sexually mature; that the roe of a large fish may weigh as much as 16 pounds (10 pounds being more nearly an average yield); that the dark brown or blackish eggs are much like those of the sturgeon in size and color, being slightly oval in form, with diameter of 1/10 of an inch more or less.

Regarding the rate of growth of paddlefish in nature we know nothing, but some observations have been made upon the growth of those placed in the storage reservoir of the Fisheries Biological Station at Fairport, Iowa, in August and September, 1916. The average gain in length of 26 specimens after a period of a little more than 2 years was at least 12 inches, and possible more. No doubt the conditions of growth here were not as favorable as in the free range of the river and larger lakes.

Of course, the paddlefish must have enemies; anything else would be too good to be true. Unless the young are as successfully concealed from predatory fish as they have been from man, or unless they are for some reason distasteful, they must be frequently devoured by predaceous fishes of their environments, such as the pike, bass, garpike, bowfin and catfish. The great number of eggs formed by each large female suggests that there is a heavy mortality somewhere in the life history of the fish which must be compensated for by heavy production. The only enemy of the larger paddlefish that has attracted special attention is the lamprey, or "lamper eel," which seems to regard the paddlefish as its special prey, perhaps because over nearly the entire surface of its body the paddlefish lack a protective armor. From 10 to 25 lampreys may sometimes be found upon an individual paddlefish, and they even invade the mouth. The marked habit of the fish of leaping from the surface of the water has been explained as a means of throwing off the lampreys.

Whatever enemies the paddlefish may have encountered in all the ages of the existence of the tribe, it has successfully survived in spite of them, until within comparatively recent years it has encountered that most interesting and dangerous of all adversaries,—that which drove the buffalo from the plains and the passenger pigeons from the air, that which destroys the forests out of which it constructs its lodging places, that featherless, scaleless, two-

legged animal known as man. A story might be written upon his habits; how he has displayed marvelous energy in industrial occupation; how he has perfected what are called fine arts, attained great skill in so-called liberal arts, and developed complex systems of thought known as the sciences; how he has mastered his larger enemies and how he still pluckily battles against the smallest and most intrepid of his foes, how, according to the promise, all things are being brought under his feet and he is acquiring dominion over the works of the fingers of the Almighty and *how he exercises that dominion!*

This would bring us to a chapter of the story of man that would not be without its sadder features. We would learn that, while he has advanced in a form of development known as civilization, he seems to have manifested certain signs of degeneration. It would appear that, in the pre-civilization stages of development, he destroyed that which threatened to destroy him, or that which he could profitably use, but that, when he became highly civilized, he became more or less blinded with the glory of successful battle and destroyed not only his enemies but those things, whether trees, four-footed animals, winged or finned creatures, upon which he depended in part, for food, raiment or shelter. If this story went into detail it could not avoid mention of the paddlefish and what the combined hero and villain of the story did to it. How many millions of years did the paddlefish withstand the changes of time while glaciers came and went, continents sank beneath the sea, and mountains rose from the deep? The laborings of the earth may at times have destroyed great quantities of paddlefish, but to the species as a whole these were trivial events. How many thousands of years did the uncivilized tribes of man fish in the water of the Mississippi and its tributaries? This was of slight significance to the ancient species. But at last something happened to the old piscine Methuselah of far greater importance than all that had gone before. Civilized man appeared upon the banks of the great river and in less than 100 years brought the paddlefish almost within sight of extinction. To judge from present indications another fifty years will bring the end, when *Polyodon spathula* will have joined the "great majority" of extinct species. And yet there is hope; for man is showing signs of an awakening, or of an atavistic return to the conditions in which he regarded useful prey as something not to be briefly enjoyed but to be conserved for all time.

But, taking things as they stand, could we blame a thoughtful

paddlefish if, after due deliberation upon its experiences with this new enemy, it should thrust its long snout above the surface of the water and cry out in anguish: "Better a thousand cycles of Cathay than 50 years of modern man!"

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson
Science Service

THE BODY GUARD

That mankind has not given up hope of an "elixir of life," in spite of the disappointments of a thousand years or more, was shown by the headlines of the papers on November 15 after Dr. Alexis Carrel had read a paper before the National Academy of Sciences at the Rockefeller Institute on "Leucocytic Secretions." The title was not engaging, but everybody knew that whatever Dr. Carrel said would be worth hearing, and when he told of the way certain fluids from the white blood corpuscles revivified dormant cells and promoted the growth of the tissues of the body, some reporters jumped at the conclusion that the fountain of immortal youth was at last in sight. Dr. Carrel was far from making any such rash promises, but he did report a very interesting extension of our knowledge of the restorative processes of the body from which we may fairly expect in time some beneficial applications.

Dr. Carrel has been able to carry on the study of such processes farther than before because he found a way of working with living cells outside the body. Ten years ago he picked out a tiny bit of the heart of an unhatched chicken and has kept it alive on glass in a warm place ever since by feeding it with suitable nutritive solutions and washing away the waste products. Now the chicken, if it had been allowed to hatch, would probably have died five years ago, but this particular bit of its heart muscle, having been better cared for by Dr. Carrel than it could have been by the chicken, is not only alive, living and growing, but seems as young as ever and there is no apparent reason why it should not continue on indefinitely, although the matter that composes it has changed more than a thousand times. Dr. Carrel has also found that the white cells of the blood can likewise be worked with outside the body. They can be cultivated on mica plates like colonies of bacteria and their influence on other cells studied at will in the laboratory. This indeed is not so surprising as his previous cultivation of a piece of muscle for these white blood cells lead a somewhat independent life even while they are in the body.

Any one who has looked at blood through a microscope will have noticed that there are two kinds of bodies floating in the fluid. There are first rolls of little round red disks looking like checker men. They carry around in a mechanical sort of way the oxygen received from the air in the lungs. But mingled with them in the blood stream are a few bodies of a different and more active sort. They are colorless and larger than the red corpuscles and have no definite shape, but adapt themselves to their situation, crawling through crevices in the capillaries and wandering about freely among the tissues. Instead of being limited as to legs and arms as we are they stick out any kind of a limb anywhere they may happen to need it at the moment like the simplest of independent animals, the amœba.

The great Russian physician, Metchnikoff, discovered that these white blood corpuscles—or leucocytes, to give them their Greek name—served a useful purpose in eating

up the microbes that invade our bodily citadel. In case of a wound they rush to the spot in increasing numbers and pile up their bodies in the breach of the skin wall. Every leucocyte is as heroic as Arnold von Winkelried. Wherever there is infection there these defenders may be found fighting the foe and perishing by the thousand in the attempt.

But now Dr. Carrel has found that they do much more than attack disease germs. They also in some way stimulate the structural cells of the body to greater exertions and promote the reconstruction of damaged tissue. They aid in the healing of wounds and the rebuilding of bones. They secrete an activating substance of some sort that revives the energies of cells that have grown tired or old. In short they act not only as a patrol force to discover and combat microbic enemies but they further see to it that the other cells do their duty. No wonder that physicians have found that an examination of the blood to determine the number and activity of the leucocytes is one of the best ways of finding out what chance a patient has of overcoming his disease.

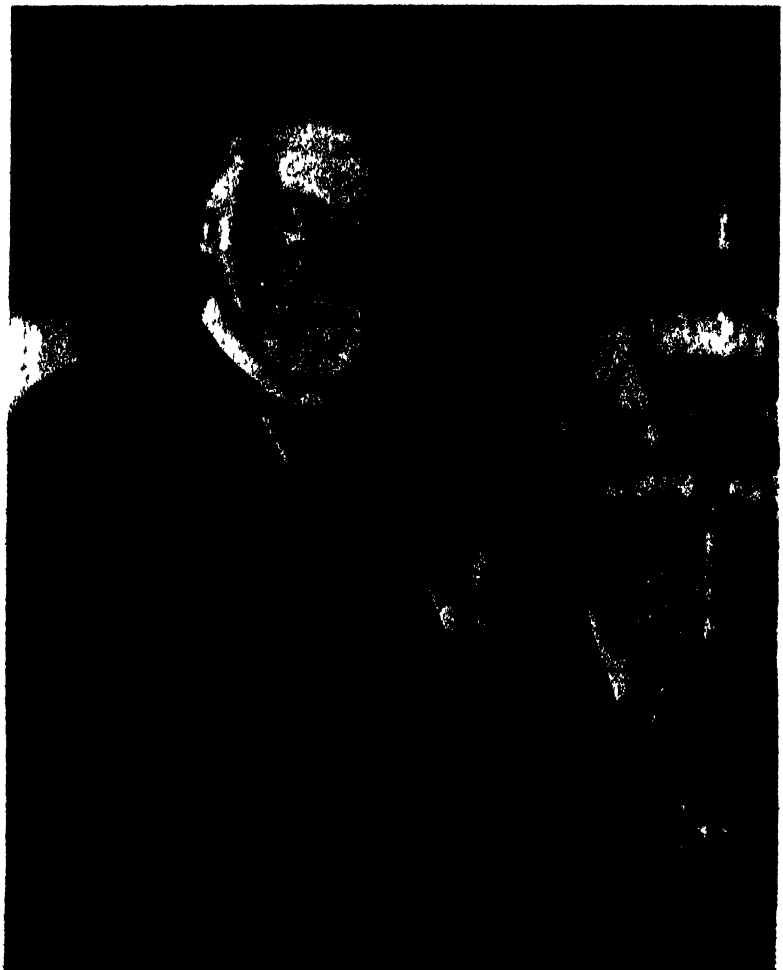
TO EXCHANGE: A CHEMICAL FOR A COLONY

The German chemists are trying to win back the colonies that the German Kaiser lost. They are offering to trade a new coal-tar drug for the African territory which Germany held before 1914, but which fell to the victors of the Great War. This territory amounts to a million square miles, or one third the area of the United States, and has been divided up by mutual agreement between Great Britain, France, Belgium and Portugal. It comprises some of the richest and most fertile land on the globe but it rests under a curse, the sleeping sickness.

This mysterious malady, that has laid waste a large part of the Dark Continent, is now known to be due to a minute parasite that lives in the blood of man and beast, and is called a trypanosome. When you look at one through a microscope you would not think that so little a creature could have so long a name or do so much harm. It looks like a smashed mosquito wiggler or a stickless kite. It propels itself along by sculling with its whip-like tail. The tsetse fly gets its living by sucking the blood of wild animals, cattle and human beings, and in so doing peddles about the microbe from sick to well. There are various sorts of trypanosomes and blood-sucking flies, each having its own habits and routes, but anyhow the infected individual suffers at first from fever and gradually sinks into an insensibility, from which the sleeper rarely wakes. This sort of sleeping sickness is peculiar to Africa and has nothing in common with the disease that has recently appeared in America except the name and somnolent symptom.

In the latter part of the last century when Europeans invaded the interior of Africa they found this micro-organism the most dangerous of the wild animals to be combated. Lions and elephants could be killed, but the tsetse fly was too small to be shot and the trypanosome was too small to be seen. How to destroy the parasite without harming the host was the question.

The first sign of a solution of the problem came in 1904 when the German physician Ehrlich and his Japanese assistant, Shiga, discovered an aniline dye which injected into the blood of a person seized with sleeping sickness would kill the parasite. This dye was named "trypan red." Two years later Mesnil and Nicolle of the Pasteur Institute of Paris found that several similar dyes made by the Bayer Dye Works were also serviceable. These dye-drugs were all derivatives of naphthalene, familiar to us all since little white balls of



DR. FREDERICK BELDING POWER

U. S. Bureau of Chemistry, who has been awarded the Flueckinger gold medal by the Society of Swiss Chemists for "invaluable work on alkaloids and etheral oil"

it drop from our clothes when we shake them out in the fall.

But none of the known dyes were sufficiently active so that they were certain to clean out the pests from the body of the patient. The Bayer company has quietly continued its search for something more powerful and equally innocuous and has at last, after 204 compounds had been made and found unsatisfactory, got one that cures. It is not a dye but a white powder, soluble in water. It was tried successfully on mice, rats, guinea pigs, rabbits, dogs and horses and finally upon man. An English patient who had suffered from sleeping sickness for a year and on whom all the customary remedies had been tried in vain, was cured by four doses amounting altogether to an eighth of an ounce. Better still it is found that a single dose will make a person immune to the disease for a long period even if infected by the fly. It is also said that the new medicine or some of its relatives will cure malaria and other tropical fevers.

Whether Bayer 205 is a plain naphthalene derivative like the earlier efforts of the firm or whether it contains arsenic like "606", which is used to destroy a similar blood parasite, is not known to the outside world for the composition is kept secret. Small samples of the drug have been furnished for experimentation to Belgian, British and American physicians but under pledge of professional secrecy. At a recent meeting in Hamburg of the German Association of Tropical Medicine one of the speakers said:

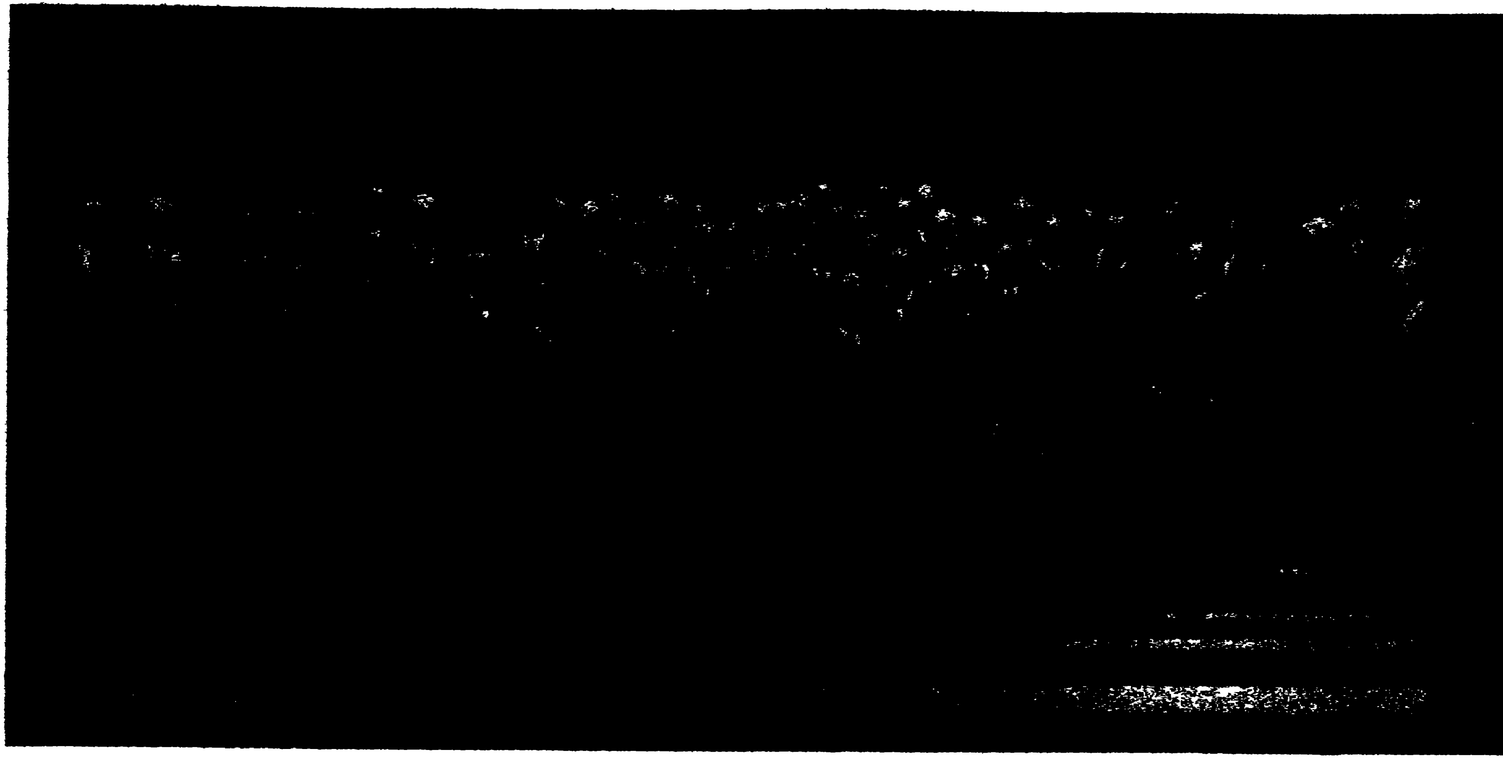
"Bayer 205 is the key to tropical Africa, and consequently the key to all the colonies. The German government must, therefore, be required to safeguard this discovery for Germany. Its value is such that any privilege of a share in it granted to other nations must be made conditional upon the restoration to Germany of her colonial empire."

It is indeed the irony of fate that the Germans should have found the means of making their colonies colonizable only after they had lost them and that their discovery must go to benefit those who took their African territories from them. But this suggestion of buying back a million square miles for a single chemical symbol can hardly be taken seriously. The chemists of other countries are already hot on their trail and with what clues they have will doubtless eventually find out the composition of the mysterious medicine. But whether Germany makes anything out of it or not, it may turn out that her scientists by this discovery will bring as much benefit to Africa as her soldiers did damage in Europe.

THE WASTEFULNESS OF AGRICULTURE

To those superstitious people who hold that nature is perfect in all her works it must come as a shock to learn that one of the most wonderful of all natural processes and the one on which all life depends, that is, the storing up of solar energy in the green leaf, is far more inefficient than any of man's machines. It is a poor steam engine that can not turn into mechanical work at least twelve per cent. of the heat energy that is fed into it in the form of coal. But a green leaf is not able to catch and hold more than one per cent. of the radiant energy that falls upon it from the sun.

What solar energy is caught and held is stored up, so to speak, in the form of starchy and woody stuffs from which the energy can be released in the form of heat when the stuff is burned. But if it is food we want from the plant instead of fuel its yield is still more limited, for we human beings with our restricted digestive apparatus can not get nutriment out of the woody fiber as we can out of the sugar and starch



MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES
At the Entrance of Schermerhorn Hall, Columbia University.

How much then of the solar energy that falls, say, on a wheat field can we get out in the form of the edible grain to furnish us with muscular energy?

Dr. H. A. Spoehr, of the Carmel Coastal Laboratory of the Carnegie Institution of Washington, has been figuring on this and reaches some startling results. An acre of ground receives in six hours of sunshine as much heat energy as would be produced by the combustion of 16.4 tons of coal. In a growing season of ninety days at this rate per day the total income of energy would amount to 1,476 tons of coal

Now what is the yield, likewise calculated in terms of heat units derivable from coal? Taking the very large crop of 50 bushels of wheat per acre and calling it all starch, we get an energy equivalent of only less than two thirds of one ton of coal.

That is to say, the farmer has received as free bounty from heaven 2,300 times as much energy as he has been able to market in the shape of food.

But don't call the farmer an inefficient fellow. He only began the cultivation of wheat in the New Stone Age, say seven thousand years ago, and see how much he has improved upon nature in the matter of yield.

And don't blame Dame Nature. She is quite indifferent to our blame or praise, but is very ready to cooperate with us when we take the trouble to learn her ways and show how they can be improved. This chlorophyll process for the fixation of solar energy, this green leaf laboratory, was one of nature's first inventions, made perhaps sixty million years ago, and she was so well satisfied with it that she made it the foundation stone of all earthly life and has kept it substantially unchanged to this day.

And man is not yet able to imitate nature in this particular process, let alone surpass her. Chemists have found it possible to make some of the simpler sugars, but only in very small amounts after long and expensive labor in the laboratory. Nothing like the neat and noiseless way that any leaf can carry it out. An effort is being made to get chemists and biologists to cooperate in working out the solution of the secret of photosynthesis—which is Greek for the constructive process of light. A "photosynthesis symposium" is scheduled for the Boston meeting of the American Association for the Advancement of Science, the last week in December, and it is hoped that this may stimulate research in this vital problem.

WHAT IS THE MATTER WITH THE ARTISTS

The most common remark to be overheard at an exhibition of ultramodern art is, "Why, these artists must be crazy!" Now to call another man "crazy" is not enlightening. It is too easy and explains nothing. Besides each one of us thinks those who differ from us in opinion, and especially in taste, are a bit wrong in the head.

But if, instead of recklessly applying the word "crazy" to everything we do not like or understand, we should analyze ourselves to find what is the reason, or rather the cause, of our instinctive repugnance, it might be helpful to us. It may be that we hate the new thing merely beause it is new. If so, we may say that we are merely suffering from neophobia. Giving a complaint a Greek name is a great consolation as every physician knows.

Or we may set a psychological expert to analyzing the people who are disturbing our minds by their unconventional notions and so find out why they show such strange tastes. Dr. Stewart Paton, lecturer on psychiatry at Princeton University, has made such an analysis of modern art in his new book, "Signs of Sanity," and

GREGOR MENDEL AND HIS FELLOW TEACHERS

in the secondary school of Brünn. Mendel in clerical attire is seated on the right. The centenary of the birth of Mendel and his remarkable contributions to heredity and genetics were celebrated this summer under the auspices of the University of Brünn. The photograph is printed by the courtesy of Professor M. M. Metcalf, to whom it was given by the monastery at Brunn

has come to the following conclusion:

"The futurist art expresses, not intellectual superiority, but very primitive emotion, and illustrates a reversion to ideas and ideals of the Stone Age. It is not what its devotees claim for it, the product of conscious intellectualization of the creative spirit. The futurist, like a good many other people who are trying to find some compensation for defects in their personality, instead of being an interpreter of new sensations and emotions, is expressing those that were more characteristic of man during the early periods of his history than they are of human beings to day The literary, as well as musical moderns, in their unsuccessful efforts to find new and startling lines of expression, have practically only succeeded in recalling some forgotten memories of very primitive ancestors. The futurists practically depend for their inspiration upon the revival of subconscious mental activities that extend far back in the history of the race, and they surrender unconsciously to the primitive vision and emotions of an almost forgotten past. Their philosophy of art is based almost entirely upon illusion and fallacy; for instead of listening to reason, they have simply succeeded in giving expression to very primitive tendencies that have been successfully inhibited by the real intellectuals who have contributed to the progress of civilization. It is of great assistance in preserving our sanity to have some appreciation of the nature and genesis of these primitive impulses and not to make the mistake of believing them to be evidences of intellectuality."

This explains why successive waves of fads in art, each more extravagant than the last, have swept over the world and shows their connection with other signs of the times. The recrudescence of superstition, the revival of race hatreds, the growth of belligerency, the glorification of brutality, the defiance of law, the contempt for intellectuality, the prevailing tendencies in music, dancing, literature and dress, as well as in painting and sculpture, all indicate a reversion to that primitive psychology that arose out of the war, or out of which war arose. The Pre-Raphaelite movement of the last century has become the Pre-Troglodyte movement of the present century. Young artists who used to go to Paris or Rome for study now seek inspiration in Tahiti or the Congo.

But while recognizing the fact that futuristic art points backward we may continue to admire it or be amused by it, according to our taste. A dip into the primitive or a flight into the unconventional may not be a bad thing for us once in a while. It will keep us from getting stuck in the mud. But if it should become epidemic and chronic—then, goodbye, civilization.

SCIENTIFIC ITEMS

We record with regret the death of Elias Judah Durand, chairman of the department of botany in the University of Minnesota; of Albert Henry Buck, from 1887 to 1904, professor of otology in Columbia University; Charles Franklin Emerson, dean emeritus of Dartmouth College, and formerly professor of astronomy and physics; Charles Albert Fischer, professor of mathematics and astronomy at Trinity College; of Emil Holmgren, professor of histology at Stockholm; of Lassar-Cohn, professor of chemistry at Königsberg; and of Oscar Hertwig, director of the Institute of Histology at the University of Berlin.

Biographies of members of the National Academy of Sciences who died during the year 1922 will be prepared as follows: A. Graham Bell, by Dr. John J. Carty; J. C. Branner, by Professor Bailey Willis; Wm. S. Halsted, by Dr. Wm. H. Welch; Henry M. Howe, by Dr. Edwin H. Hall; Alfred G. Mayor, by Dr. Charles B. Davenport; Alexander Smith, by Professor W. A. Noyes.

To Dr. Fridtjof Nansen, the Norwegian Arctic explorer and zoologist, has been awarded the Nobel Peace Prize for his work in relieving the starving populations of Russia and Asia Minor and for his endeavors to promote the brotherhood of nations.

THE Lalande Medal of the Paris Academy of Sciences has been awarded to Dr. Henry Norris Russell, director of the Princeton Observatory. The Janssen Medal goes to Dr. Carl Stormer, professor of pure mathematics at the University of Christiana, for his work on the aurora borealis

AT the anniversary meeting of the Royal Society on November 30, its awards are to be conferred as follows: Royal medal to Professor C. T. R. Wilson, for his researches on condensation nuclei and atmospheric electricity, and to Professor J. Barcroft, for his researches in physiology, especially in respiration; the Copley medal to Sir Ernest Rutherford, for his researches in radioactivity and atomic structure; the Rumford medal to Professor Pieter Zeeman, for his researches in optics; the Davy medal to Professor J. F. Thorpe, for his researches in synthetic organic chemistry; the Darwin medal to Professor R. C. Punnett, for his researches in the science of genetics; the Buchanan medal to Sir David Bruce, for his researches and discoveries in tropical medicine; the Sylvester medal to Professor T. Levi-Civita, for his researches in geometry and mechanics; and the Hughes medal to Dr. F. W. Aston, for his discovery of isotopes by the method of positive rays.

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THE MAYENCE BASIN, A CHAPTER OF GEOLOGIC HISTORY

By Professor EDWARD W. BERRY
THE JOHNS HOPKINS UNIVERSITY

GEOGRAPHERS have done well in emphasizing the influence of geography upon human affairs, and the history of strategic regions whether they be river valleys, coastal plains or other lanes of attack, or merely paths of migration of races, or overland trade routes—and all three are usually the same—is one of the most fascinating of subjects. The more primitive the race the more dependent is it upon local environment, and we find the men of the Old Stone Age passing along and settling in those regions in Europe that have since, times without number, been regions of envious neighbors and shifting sovereignty.

No equal area is of more interest to the student of later geologic history than the Mainz basin, or Mayence basin as it is frequently called, for it belonged to France from 1797 to 1814. One would suppose that it was a sharply defined geographic unit, such as Steinheim, for example, but it has no especially well-marked natural boundaries on all sides, neither is it a political entity; nevertheless the name is well chosen.

The Rhein valley, from where it turns to the northward out of the Jura mountains at Basel, winds northward in a wide valley some thirty miles in width, and maintains this direction for a distance of about 225 miles. Then it turns sharply to the west and, after flowing along the southern flank of the Slate Mountains, it turns again northward at Bingen into the justly celebrated Rhein gorge.

The juxtaposition of lowland and upland are features here brought about by breaks and slips in the earth's crust, and the plain of the Rhein from Basel to Frankfurt is one of the best known as well as the most perfect example of a sunken earth seg-

ment (graben) bounded on either side by fault scarps. The strata of the Vosges Mountains on the west side dip to the westward, and they are exactly duplicated in the Black Forest on the east side, where they dip in the opposite direction, and a tyro can see that here are the remains of a great crustal arch or anticline with a slice about 30 miles in width missing from the crest of the arch.

The city of Mainz itself is picturesquely situated on rising ground on the left bank of the Rhein, just where the westerly flowing Main joins that stream. It is one of the oldest cities in Germany, and its site was recognized as a strategic point by the Celts, who had a settlement here. The Romans under Drusus, Augustus' son-in-law, built a fortified camp here about 13 B. C., and this became finally the capital of *Germania Superior*, and in consequence grew in size and importance, with the result that it was repeatedly razed by Alamanni, Vandal and Hun. Many relics of the Roman period escaped total destruction and still gladden the tourist. The Chatti, who inhabited the vicinity in Roman times, are perpetuated in the name Chattian, which Fuchs proposed in 1894 to designate the uppermost stage of the Oligocene, since the rocks of this age are so well developed and abundantly fossiliferous in Hesse.

The town of Mainz thrived during the long reign of Charlemagne and became a free city in 1118. It is not to be wondered at that it is still strongly Catholic, for it was the see of an archbishopric as early as the eighth century, and the tomb of Boniface, the first archbishop, is still to be seen in the rather notable Romanesque cathedral dating from the tenth century, along with the tombs of Frauenlob, the Minnesinger, and many of the electors, for the archbishopric was one of the seven electorates of the Holy Roman Empire. In the thirteenth century Mainz was the center and main support of the league of Rhenish towns, but the illiberal rule of the archbishops and the military struggles between rival claimants resulted in a gradual decline of the city during the fifteenth century, although it was here in 1450 that Johann Gutenberg set up his first printing press.

Although ideally located for commerce, this has always been hampered by its strategic position from a military point of view, so that it has been greatly distanced by its easterly neighbor, Frankfurt. No place is more redolent with historical associations than Mainz, although Strasburg, 150 miles up the valley, perhaps rivals it in modern interest.

The Rhein plain is nowhere over 650 feet in elevation, and from Spires on down to Bingen it is only half this height. The Mainz basin may be considered as an inverted triangular area with its

base formed by the fault bounding the southern margin of the Taunus, and marked by the town of Wiesbaden. The eastern limb may be considered as formed by the highland masses of the Vogelsberg, Spessart and Odenwald, the last a northward continuation of the Black Forest (Schwarzwald), from which it is separated by the river Neckar. The western limb, with its base resting on the Hunsrück, is formed by the Hardt, a declining northward continuation of the Vosges Mountains, which rises, however, in the Donnersberg, west of Worms, to 2,254 feet. The apex of the triangle may be placed at Spires. There is no clear demarcation between the Mainz basin and the upper Rhein plain, and similarly to the northeast the low country with characteristic Tertiary geology continues between the Taunus and the Vogelsberg to the river Lahn at Giessen. This latter region is the brown coal area known as the Wetterau and celebrated for its fossil plants and lignite.

The bounding uplands rise rather abruptly from the basin, being largely determined by faults, and are attractive vineyard covered rural districts, for grape raising supports the main industry of wine making, for which the region is famous. For our knowledge of the geology of the basin, we are principally indebted to a long succession of German geologists and paleontologists who have diligently studied the deposits and fossils of this classic region,

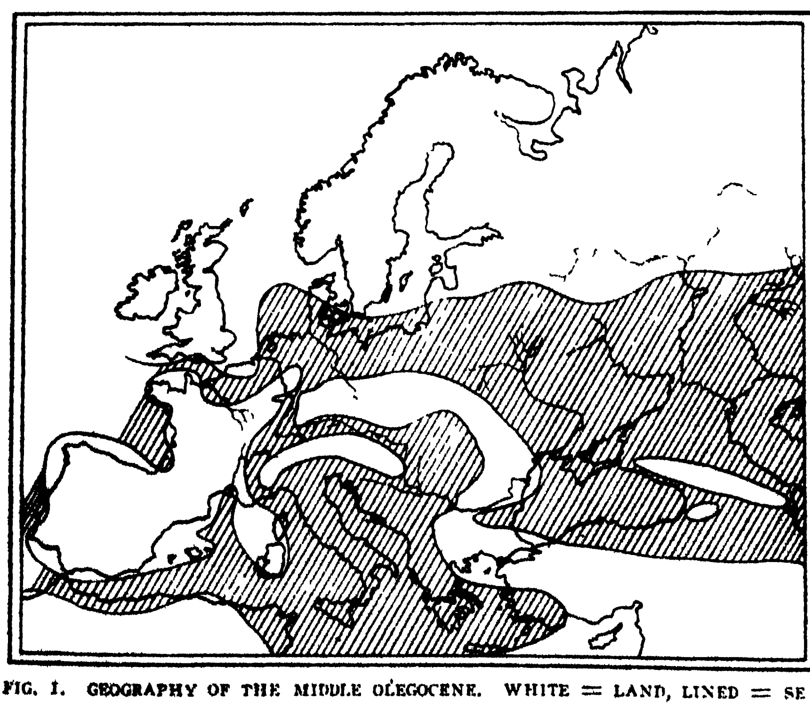

FIG. I. GEOGRAPHY OF THE MIDDLE OLIGOCENE. WHITE = LAND, LINED = SEA.

many of whom have been aided by the scientific society and museum at Frankfurt.

The geological history of the Mainz basin as an individual unit, as distinct from its history as a part of a larger geological province, begins in the Oligocene Tertiary with the depression of the middle Rhein valley between the Vosges-Taunus and the Black Forest-Odenwald regions of older rocks. This depression brought about the first flooding of the Mainz basin, as such, by the Oligocene sea, which at that time was advancing over the old land surface of Europe. In this area this old land surface which forms the basement rocks of the Mainz Tertiary sediments consisted of middle and upper Permian (Rothliegende) with its quartz porphyry and melaphyr igneous intrusions, of hard Devonian shales or slates, of the Rhein schists of the Odenwald or of old basaltic sheets.

At that time the geography of Europe was very different from what it is at the present time, much of the central and southern part of the continent being submerged, as may be seen in Figure 1. An enlarged Spanish peninsula was united with an abbreviated France to form a large Western Island, from which a southeasterly peninsula included most of Corsica and Sardinia. This island was separated by narrow seaways from the enlarged British Isles on the north and from Africa on the south. On the west rolled the Atlantic, but on the east the Western Island was separated from the sausage-shaped island marking the present site of the Alps by a narrow strait, and a similar strait separated it from the long sigmoid peninsula that extended all of the way from Iran and Asia Minor through the Balkan, Carpathian and Bohemian massifs to the Black Forest region of southern Germany. The site of the future Caucasus mountains was also an island, a great sea extending eastward from the North sea, covering north Germany, all of southern Russia and northern Armenia. Most of Italy was submerged, the Oligocene Mediterranean sweeping over Italy and the lands bordering the east Adriatic as far as Thrace.

The Mainz basin at this time was an irregular strait connecting the North German sea with the Mediterranean, narrowest just north of Frankfurt, where it was only about 15 miles across and rather shallow. According to Haug the marine fauna found in these initial deposits of the Mainz basin—the Meeressand—is so like that found in the sands of Fontainebleau in the Paris basin that there must have been a direct sea connection between the two by way of the Saar and Lorraine regions, but there is no corroborative evidence for such a geographic pattern. Tidal or other currents were sufficiently active in this region at the beginning of our history to prevent the accumulation of sediments finer than sands,

FIG. 2. RESTORATION OF THE MAINZ MANATEE HALITHERIUM SCHINZI KAUP
ABOUT $\frac{1}{37}$ NATURAL SIZE

and erosion was active at this time on the bordering lands, for the old shores are lined with conglomeratic beds.

These initial deposits of the Mainz basin constitute the Meeressand of German geology. They are essentially the littoral and shore sands of the transgressing sea—older in the middle part of the basin and progressively younger in passing outward to its borders, being gradually replaced in the deeper and quieter parts of the basin by first sandy muds and then more pure muds (clays). The fauna that has been found in the Meeressand is very extensive and almost entirely marine in character. Among the mammals are a sea cow (Halitherium) and seal (Phoca), and a hornless rhinoceros (Aceratherium) whose grave happened to have been the sea floor instead of its native forests. There are traces of four reptiles, including two turtles; and four fishes, all of which were sharks. A barnacle and some 30 different ostracod crustaceans have been recognized. Molluses were numerous and varied (59 gastropods including a land snail, 2 scaphopods, 2 chitons and 55 pelecypods). There were 3 brachiopods, 6 bryozoa, 2 sea urchins, 10 corals and about 100 foraminifera.

The most striking denizen of the Mainz waters was the Oligocene sea cow or manatee (Halitherium) whose bones are so common in the Meeressand and the partially overlying Rupel clay. A restoration of this animal is shown in Figure 2, where for the sake of clearness one individual is shown lying on the shore, although these animals never left the water in life. During Eocene times, many thousand years earlier, in the then humid region of Nubia, the Ungulate ancestors of the manatee and dugong forsook the competition of the terrestrial environment and gradually became adapted for an exclusive aquatic mode of life, eventually entirely losing their hind limbs, although these are still retained in the Libyan Eosiren, having the fore limbs modified to form flippers, developing a horizontally flattened fluke on their hind ends to facilitate their vertical movement in the water and having the bones become extraordinarily heavy to aid them in remaining submerged while browsing on the aquatic vegetation of the shallow waters.

These animals constitute the order Sirenia, so named from the quaint conception of the early naturalists that the existing forms were sirens or mermaids. Ancestral forms were probably common along the shores of the Mediterranean lands of both hemispheres during the Tertiary, continuing in Europe as late as Pliocene times when they are found as far north as Belgium. The Mainz manatee, *Halitherium schinzi* Kaup, shown in the accompanying illustration, was a slow inactive vegetarian of the estuaries, which, like its mod-

ern representatives, was probably gregarious in its habits and never ventured far from the shallow waters where its food was abundant.

All but two of the dozen known genera of sea cows are extinct. These occur only in the warm, mainly tropical regions, although rhytina, the northern sea cow of Behring Sea, survived in that region until exterminated by man in the eighteenth century. The existing sirenians comprise three oriental species of Dugong ranging along the coasts from East Africa to eastern Australia, and three species of Manatee found from southern Florida to Brazil and on the west coast of Africa between latitudes 16° North and 10° South. The most striking difference between the manatee and the dugong is in the tusks with which the male dugong is armed. The latter is also more of a sea margin type and tidal feeder, whereas the manatee is more of a river form, the African species occurring inland to Lake Tchad, and the Amazon species ranging to the head waters of the great system and present in abundance in the summer flooded lands at the foot of the Andes. The present and past distribution of the sirenians is shown in the accompanying sketch map, Figure 3.

With the progress of time the sediments known as the Meeressand passed gradually both seaward and upward into more muddy materials, the Rupelthon or Septaria clay, so-called because there was enough calcium carbonate in the deposits to bring about the formation of the jointed concretions known as septaria, and which

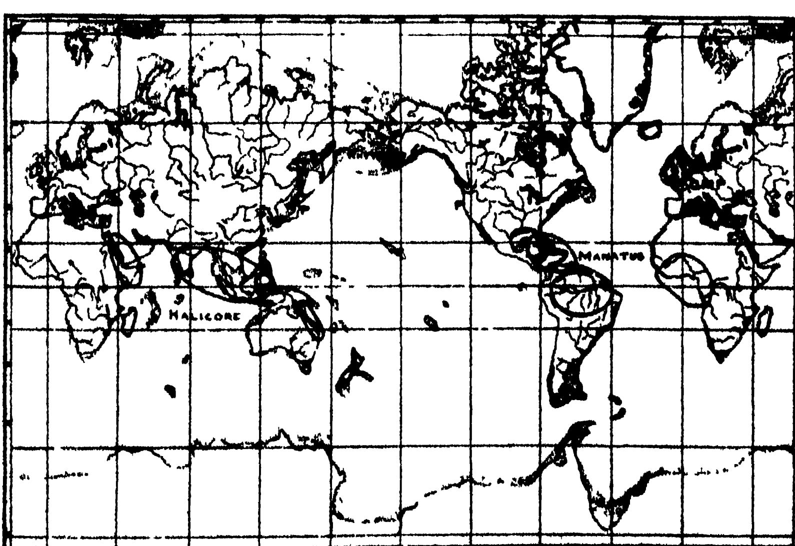

FIG 3. GEOLOGIC AND GEOGRAPHIC DISTRIBUTION OF THE SIRENIA. E—EOCENE, O—OLIGOCENE, P—PLIOCENE

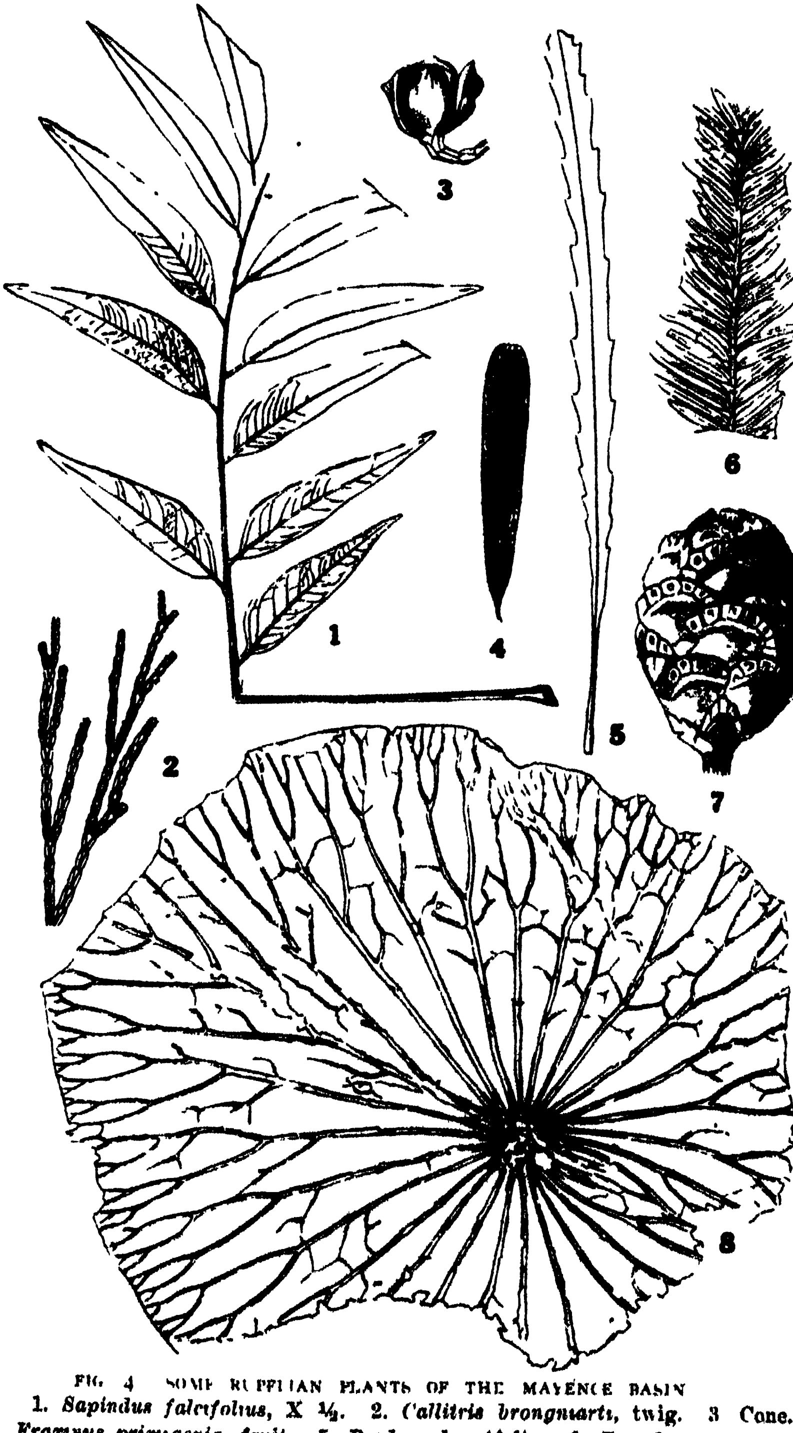

FIG. 4 SOME RUPELIAN PLANTS OF THE MAYENCE BASIN

1. *Sapindus falcifolius*, X ½. 2. *Callitris brongniarti*, twig. 3 Cone. 4. *Fraxinus primigenia*, fruit. 5. *Banksia longifolia*. 6. *Taxodium dubium*, twig. 7. Cone. 8 *Nelumbium buchi*, X ½.

are a prominent feature of these clays. They are almost always more or less sandy and accumulated in the central part of the Mainz basin to a thickness of over 350 feet. They are capable of a rough three fold separation, the lower transition beds being sparsely fossiliferous.

The discovered fauna includes the sea cow, a turtle, some 36 fishes including rays and many sharks, such as to-day are represented in coastal waters of warm climates. There were two crabs and 17 ostracod crustaceans, a starfish and 79 foraminifera. Molluscs were fairly abundant (19 gastropods, 1 scaphopod, 15 pelecypods) and included three of those small pelagic type known as sea butterflies (Pteropoda). At this horizon there have also been discovered 72 different plants that grew on the surrounding shores. Among these were palms, incense cedars, representatives of our American sequoias and bald cypress, pines, bayberry, figs, laurels sassafras, cinnamon, ash, soapberry and myrtle; many representatives of warm climate genera such as Pisonia, Echitonium, Myrsine, Bumelia, Bombax, Terminalia Eugenia, Myrcia, etc. Some of these are shown in Figure 4.

As the sediments of the Meeressand graded imperceptibly into those of the Septaria clay, so those of the latter passed gradually into those known as the upper Meeressand, or Schleichsand, as it is commonly called. This last is a fine-grained micaceous sand with a considerable admixture of silt and reaches a maximum thickness of about 160 feet. Its fauna is similar to that of the Meeressand, but is less abundant and varied. It consists of a reptile, a shark, a barnacle and 8 ostracods, 24 marine and brackish gastropods and 14 land and fresh water gastropods, 39 bivalves, mostly muddy bottom types, a sea urchin and 17 foraminifera. Thirty-five species of plants, essentially similar to those of the Septaria clay, mark the contributions from the forested shores. From a larger viewpoint the Meeressand, Septaria clay and Schleichsand, which constitute the Rupelian stage of the Oligocene, can be considered as essentially a sandy unit beginning with the sands of the transgressing sea, with a middle period of offshore muds and reduced run-off from the land, and a late interval of agitated waters as the basin shallowed and the run-off from the bordering lands increased.

A shallowing or filling of parts of the basin results in the appearance of sediments representing brackish and fresh water which follow those of the Rupelian. These are the Cyrenia marl, essentially calcareous muds with some buried swamp deposits, the Melania clay, a mud deposit largely developed in the Rhön region northeast of the basin beyond the Frankfurt straits. This progressive shallowing, which first becomes apparent in late Rupelian

times continues throughout the deposition of the Cyrenia marl in the basin, eventually resulted in emergence, and this emergence is marked in places by the remains of stream gravels and sands, and fresh water limestones containing fossil land snails. The fossils of the Cyrenia marls comprise representatives of 9 mammals including four different rhinoceroses, 4 fishes, 20 crustaceans, 21 bivalves, 21 marine and brackish and 16 land and fresh water gastropods, 1 sea moss, 11 foraminifera and 2 aquatic plants, including Chara.

The snail limestone, of local occurrence around the northern and western borders of the basin, is found in disconnected small patches, and from these very many fresh water and land shells have been described. The old northwestern bay south of Bingen and southwest of the site of Mainz was entirely occupied by fresh waters at this time in which were deposited the fresh water marls (calcareous clays). The more central portions of the basin, in all probability cut off from direct communication with the open sea, was filled by water rendered brackish by the influx of fresh water from the streams which flowed into it. According to the current interpretation of the Germans, these Cyrenia marls, lignitic clays, fluvial gravels, sands and fresh water limestones constitute the Chattian or closing stage of the Oligocene. French paleontologists, with probably greater justification, consider the Chattian stage to include the three succeeding divisions to be described presently, and which the Germans refer to as the lower Miocene or Aquitanian stage.

Overlying the brackish or fresh water sediments just mentioned there occur a series of limestones, marls and sands that indicate a slight deepening of the basin with a temporary renewal of the connection with the Mediterranean. This deepening resulted in a recession of the shores so that the marine sediments of the first or Cerithium stage transgressed the continental deposits of the preceding stage. At this time a shallow gulf about 30 miles in width extends northward beyond Mainz and Frankfurt, becoming sandy at its head north of the latter place. The fauna of the Cerithium stage is limited, comprising 9 species of mammals whose carcasses washed into the bay from the surrounding lands; a barnacle and 4 ostracod crustaceans; 19 gastropods, largely estuarine types and characterized by several species and varieties of the genus Potamides which is the basis for calling these deposits the Cerithium beds; 11 mostly estuarine bivalves and 4 foraminifera.

The Cerithium beds were followed by the Corbicula beds, so-called from the abundance in them of the species *Corbicula faujasi*. The time of deposition of the Corbicula beds is marked by a general

elevation or a northward tilting of the region, which gradually cut off the connection with the Mediterranean at the south and widened the basin of sedimentation northward in the Wetterau and Vogelsberg regions southeast of Giessen, and in this more northern area were laid down sands and clays including the leaf sandstone of Münzenberg, so-called from the abundance of the leaves of land plants which it contains. The depauperate fauna comprises 8 mammals, 2 reptiles, 1 fish—a perch, 10 ostracods, a caddis fly larva, 32 gastropods, mostly brackish and fresh water forms, 4 brackish or fresh water bivalves and 3 foraminifera. The fossil plants comprise about 33 species and include palms, bald cypress, alder, beech, elm, fig, willow, cinnamon, maple, buckthorn and walnut. This flora appears to lack most of the warmer climatic types that characterized the earlier Oligocene of this region and hints at a slight climatic change.

The continued change of level progressively restricted the area of sedimentation, which now, during the time occupied in the deposition of the Hydrobia beds became a lake, which was about 135 miles in length from north to south and about 50 miles wide at its widest part which was at about its middle from what is to-day Bingen on the west to Darmstadt on the east. Only a few relics of the former marine faunas of the basin, like the muscle (Mytilus) and a couple of foraminifera in the earliest layers, survived and became buried in the sediments of the Hydrobia lake. These lake beds do contain, however, a considerable representation of the contemporary mammal fauna of the surrounding lands. These amount to 37 different species and include opossum, both horned and hornless rhinoceroses, the tapir, squirrel, musk-rat, mole, shrew, bats, primitive pigs, bear-like dogs, primitive deer, mustelines, etc. There have also been found in these beds the remains of 2 herons, 11 reptiles, mostly turtles, 4 amphibians, 4 fishes, 9 ostracods, 1 caddis fly larva, 54 fresh water gastropods and two bivalves, as well as occasional leaves of land plants and Chara fruits. In the Rhön region lying to the eastward of the northern bay of the Hydrobia lake extensive beds of clay with swamp deposits (brown coal) were being formed during the time the lake was silting up and disappearing. These lignitic clays contain considerable floras, that from Wieseck near Giessen being probably of this age. The lignitic clays of Elm, characterized by extinct mammals known as Anthracotheres and belonging to the genus Brachyodus is also of this age, or it may be slightly younger, some authors referring it to the Burdigalian stage of the Miocene.

A very long period of emergence and erosion followed the close of the last Oligocene deposits—the Hydrobia beds, probably con-

comitant with and caused by the same influences which were bringing about the initial uplifts in the region of the Alps. This interval of emergence and erosion and lack of sediments, in accordance with the interpretation presented here, lasted throughout the Aquitanian, Burdigalian and Helvetian stages of the Miocene or about half way through that epoch. The oldest true Miocene of the Mainz basin consists of continental beds now found only in its eastern part. In the western and southern parts of the basin Miocene sediments of any kind appear to be entirely absent.

This oldest Miocene is known as the land snail marl and it is represented in the region from Darmstadt northeastward. These beds correspond to the Sylvana beds found elsewhere in Germany, and are of Tortonian age. They contain patches or stocks of algal limestone, and have yielded a fauna which is very limited aside from the numerous species of land and freshwater snails. There are several small land mammals and birds preserved in these deposits, as well as a land tortoise and a tree toad. The fishes include a species of Lepidosteus of the ancient and waning race of gar pikes. Two fresh water ostracods and the remains of a water lily (Brasenia) also occur at this horizon. Vulcanism is a prominent feature of the history of the region from this time onward for several thousand years, the lava flows from the Vogelsberg dating from this time.

Immediately succeeding the land snail marls are another series of marls especially characterized by the presence of the gastropod shells known as *Melania escheri* and *Melanopsis marzolina*, and usually considered to be of late Miocene or Sarmatian age. These were followed in the Frankfurt region by muds and swamps which formed the lignitic clays characterized by the gastropod genus Prososthenia and often called the Prososthenia beds. The limited fauna found in these beds includes a frog, 2 fishes, 6 gastropods and 14 insects. The fossil plants found at Salzhausen in the Wetterau are considered to be of this age, but may be older. The flora that is known to have flourished at this time numbers about 50 species and includes a fan palm, coniferous trees representing the genera Glyptostrobus, Sequoia, Libocedrus, Widdringtonia, Taxodium and Pinus—only the last being present in the flora of modern Europe. This abundance of coniferous trees indicates somewhat dryer soil conditions and a more temperate climate, and this influence is borne out by the deciduous trees represented, which include birch, alder, oak, beech, hazel, elm, plane tree, willow, pistacia, maple, buckthorn and grape. This is a quite modern assemblage, and the invasion of the region by the grape is to be especially noted. The following represent types of trees which were constitu-

ents of the Mainz forests at that time, but which subsequently disappeared from the continent of Europe—sweet gum, fig, persimmon, soapberry, walnut and hickory.

Following the Prososthenia beds were continental sands and stream gravels which are widely spread in Germany and quite generally known as the Dinotherium sands. They were contemporaneous with the clays containing the bivalved mollusc, *Congeria kayseri*, and are referred to the Pontian or latest Miocene stage. The last basaltic sheets of the Wetterau and the Rhön were contemporaneous with these sands and clays. These Dinotherium sands contain the relics of a highly interesting mammal fauna—the so-called Eppelsheim fauna found near the historic town of Worms.

This fauna includes an ape—a true gibbon (Pliohylobates)—a beaver, two elephants—the large *Tetralophodon longirostris* and the giant dinothere, *Dinotherium giganteum*. Six carnivors have been found, including two sabre toothed tigers, a wolf-like dog, a hyena of the same species as lived in the grottos of Pentelican marble in Attica (Pikermi). There were two hornless rhinoceroses and a large Dicerorhinus of the Sumatran type, a horse and a tapir, four different pigs and five species of deer. The last are especially interesting since in the Pikermi fauna of Greece which is the same age or very slightly younger than this Manz basin fauna, the deer of the latter are replaced by a variety of antelopes, denoting a more open plains country which has been eloquently pictured by Gaudry. The Mainz deer include a musk deer (Hyaemoschus), a hornless deer (Palaeomeryx), a true deer (Elaphus), and two cervulines or muntjacs (Dicrocerus). The Mainz country of this time was obviously more heavily wooded and swampy than Greece or the emerged Aegean plain, which were land at that time.

The Dinotheriums are supposed to have entered Europe from Africa during the lower Miocene at a time when southern Europe was a region of low forests comparable with the existing forested country of East Africa. They are very imperfectly known but apparently lived on in Europe through Miocene times. Two species are known from the lower Manchhar beds (Sind) of India, and the genus survived in the later Miocene of the Punjab—forms related to the Mainz *Dinotherium giganteum* having been reported from the older Siwalik beds of the Punjab (India). The Dinotheriums constitute a sub-order or super-family of the elephant phylum, and were largely fluviatile or semi-amphibious in their habits—perhaps the term palustrine describes their habits more adequately, since they were essentially denizens of swampy areas. The Mainz species was the giant of the race and because it is so imperfectly known it seemed desirable to attempt its portrayal, although it should be

FIG. 5. RESTORATION OF DINOTHERIUM GIGANTEUM KAUP, ABOUT 1/35 NAT. SIZE

borne in mind that nothing approaching a complete skeleton is available for such a restoration. (See Figure 5.)

The contemporaneous flora is less fully represented by fossils in the Mainz basin than at synchronous localities in France, Italy and Austria. From Laubenheim near Mainz the paleobotanist Goeppert identified the following plants, which, however, give us a very imperfect picture of the actual botanical composition of the forests and swamps of that time: *Quercus furcinervis, cuspidata* and *undulans, Fagus deukalionis* and *castaneaefolia, Liquidambar europaeum, Laurophyllum crassifolium, Echitonium sophiae, Bumelia oreadum, Aralites lanceus* and *Dombeyopsis lobata*. Except for the oaks and beeches these all belong to genera no longer found in the European flora.

Following the deposition of the Dinotherium sands, the geological record of the Mainz basin is a blank in so far as sedimentary beds are concerned, although a basalt sheet dates from this time, until upper Pliocene times. These upper Pliocene deposits are stream, lake and flood plain sediments—sands, clays and lignites (brown coal). Their contained relics of the life of the times include a few fresh water shells and the remains of an extensive flora. This flora consisted of many pines, larch, spruce, fir, sequoia, bald cypress, incense cedar callitris, ginkgo, birches, poplars, beech, hazel walnut, hickory, elm, sweet gum, many grapes, hackberry, maple, water lilies, box, buckthorn, holly, sumach, etc.

It is of exceedingly great interest because of the number of elements which it contains representing the Holarctic north temperate flora, and which at the present time have long been entirely

extinct in the European area. Among the striking examples of what happened to this Holarctic flora in Europe during the Pleistocene glaciation are walnut and hickory whose fruits are like those of existing North American forms; bald cypress, indistinguishable from our American tree; Callitris—now north African; Torreya—now American and Asiatic; Cephalotaxus and Ginkgo, both now eastern Asiatic; and other equally striking cases which might be mentioned. Some of these plants are shown in Figure 6.

Then came the Pleistocene Ice Age, which, during its four periods of glaciation worked havoc with the noble races of Holarctic animals and plants that formerly inhabited Europe. In the Mainz

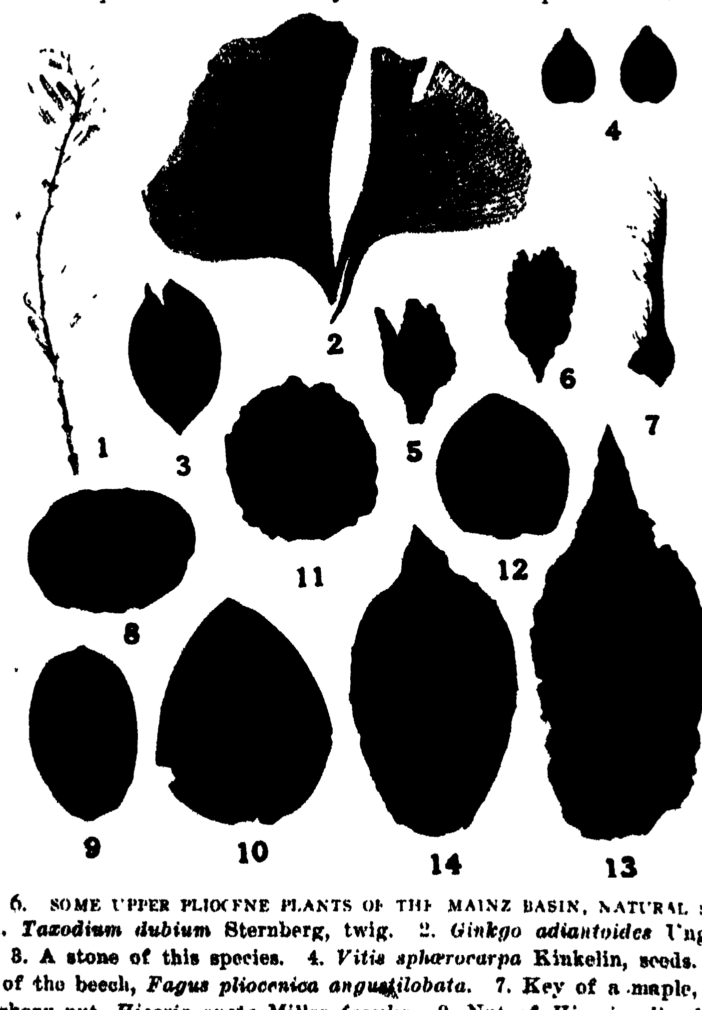

FIG. 6. SOME UPPER PLIOCENE PLANTS OF THE MAINZ BASIN, NATURAL SIZE.

1. *Taxodium dubium* Sternberg, twig. 2. *Ginkgo adiantoides* Unger, a leaf. 3. A stone of this species. 4. *Vitis sphærocarpa* Kinkelin, seeds. 5, 6. Burs of the beech, *Fagus pliocenica angustilobata*. 7. Key of a maple, Acer. 8. Hickory nut, *Hicoria ovata* Miller *fossilis*. 9. Nut of *Hicoria oliværformis*. 10. Half of nut of *Hicoria sattleri*. 11. Nut of *Juglans nigra fossilis*. 12. Nut of *Corylus avellana fossilis*, the hazel. 13. Butternut, *Juglans cinerea fossilis*. 14. Half of a butternut.

basin the Pleistocene deposits are sands, gravels and loams, with the fine-grained wind-blown material known as loess. From the great Scandinavian center of accumulation the continental ice sheet spread southward, crossing the lower Rhein and reaching beyond the site of Berlin, but failing to reach the Mainz region by about 150 miles. The Alps, which at the close of the Tertiary had attained their modern proportions, were also the scene of extensive glaciation, sending out their glaciers into the surrounding lowlands, but these reached only as far as the upper Rhein valley a long distance above Mainz, so that the Mainz basin itself remained

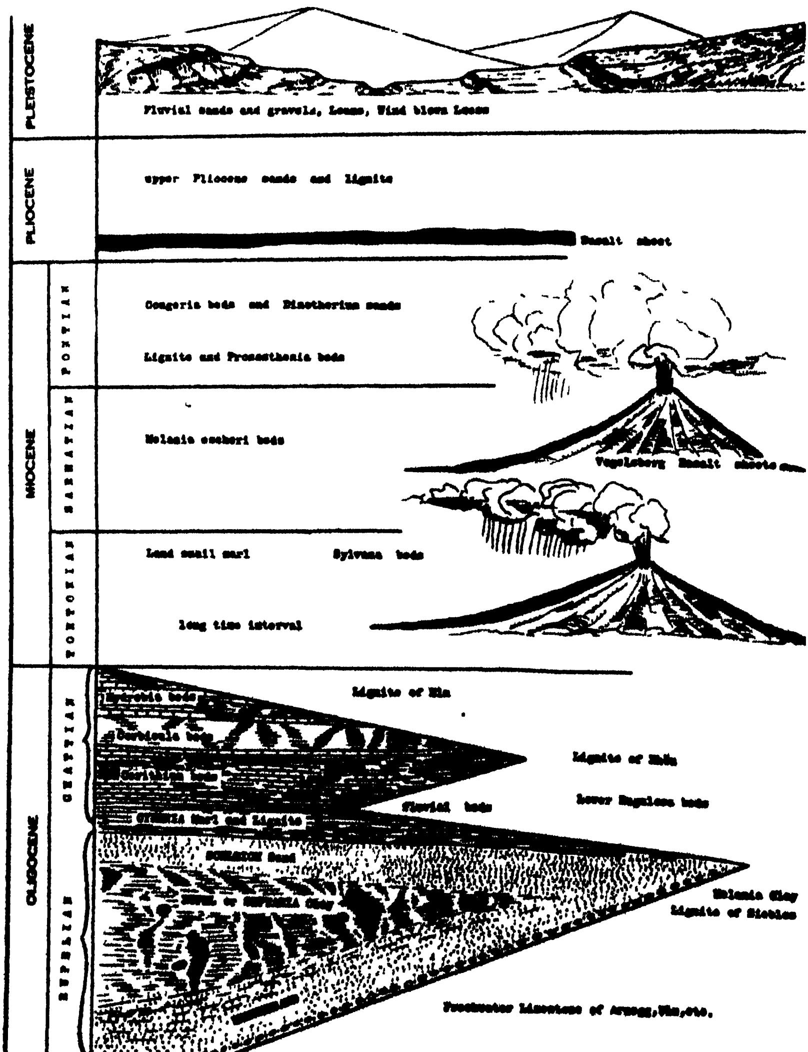

FIG. 7. DIAGRAMMATIC SUMMARY OF THE GEOLOGIC HISTORY OF THE MAYENCE BASIN

unglaciated. It shared the general history of Europe, with the extreme fluctuations of glacial and interglacial periods, which resulted in the extermination of so many forms of life. It was during the Pleistocene, too, that the men of the Old Stone Age arrived in western Europe, but in these later times the Mainz basin loses the identity which attaches to it from Oligocene to Pliocene times, and its later history is henceforward a part of the general geologic history of Europe and need not prolong our discussion.

I have attempted a diagrammatic summary of the history of the Mainz basin in the accompanying illustration constituting Figure 7, and which I hope is self explanatory.

LICHENS—IMPOSSIBLE PLANTS

By ALBERT W. C. T. HERRE
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AMONG the most singular and inexplicable of organisms are those known to botanists as lichens. Common folks lump them together as "moss" along with liverworts and the true mosses, if indeed they observe them at all. But as a rule they are unnoticed, though we may find scattered through the works of poets and novelists many references to lichens. For example, Praed wrote

> O'er the natural tomb
> The lichened pine rears up its form of gloom,

While Bridges saw

> The red roofs nestle, oversprent
> With lichen yellow as gold.

Whitman, hunting for wild flowers, says

> Here oft we sought the violet, as it lay
> Buried in beds of moss and lichens gray,

but Erasmus Darwin with uplifted eyes looked to

> Where frowning Snowden bends his dizzy brow
> Retiring lichen climbs the topmost stone.

The finest description and most vivid picture of lichens limned by poets is perhaps that of prolific old J. G. Herder, who nearly a hundred and twenty-five years ago wrote these lines:

> Wer hat je de Flechten, wer hat die Moose gezählet,
> Deren Frühling beginnt, wen Fröste den Herbst entblättern,
> Deren üppiger Wuchs die Scheitel ätherischer Alpen
> Da, wo sie Flora verlässt, mit tausend Farben bekleidet?

Of a different stamp are the many references which do not distinguish them from the mosses, as in the familiar introduction to Longfellow's "Evangeline,"

> This is the forest primeval. The murmuring pines and the hemlocks,
> Bearded with moss and gray,

or Mrs. Hemans's "red cup-moss."

A lichen is not an organism or species in the same sense that we use the word in referring to other plants or animals. A coconut crab or the tree on whose fruit it feeds, an apple tree or an

ant crawling along its trunk, each is a distinct species, a definite entity of more or less homogeneous structure with organs and tissues of a common primary origin and a definite common specific heredity. Each of the examples cited is the product of the union of a sperm and an egg cell from like parents and can come into being in no other way. It is true that some animals and many plants propagate wholly or in part parthogenetically, that is, without the fertilization of the egg, and that others increase in numbers through some form of somatic or cell division. But no matter what the exact method, it is impossible to have a coconut crab whose parents were anything but coconut crabs, or to get a cross between a fern and a flowering plant, a liverwort and a moss, a shark and a sardine, a bat and a bird.

Yet when we examine lichens we find an entirely different state of affairs. A lichen is composed of two entirely unlike organisms, belonging to two entirely distinct and altogether different groups of plants. Biologically a lichen is therefore composed of and is the resultant of the interaction of two distinct and utterly unlike living organisms which go to make up its body, and in consequence is what we may term for lack of a better distinction a physiological and not a morphological species.

If we section a lichen and examine its anatomy we find it to be made up of a fungus and an alga. The form and texture of most lichens is due to the fungus, its hyphæ or filaments often being compacted at the surface to form a thick strong cortex, while from the lower surface they extend as rhizoids or otherwise simulate roots. The alga on the other hand is nearly always distributed in a layer within the body of the lichen but much nearer the upper or outer surface, so that in section it forms a streak of bright green enmeshed in the white threads of the fungus. In the gelatinous lichens, such as the *Collemaceae* and the *Ephebaceae* and a few other families, the shape or habit of growth of the lichen is due to the algal element, the fungus making up but a small part of the lichen.

A more careful microscopic examination of the structure of a lichen shows that the algal cells are not only surrounded by fungal hyphæ, but that the latter are closely appressed against the algæ or even send haustoria into the algal cells, in either case drawing from them by osmosis elaborated foods and often destroying them.

In ordinary fungi the vegetative part is usually reduced in size since it obtains its food already prepared, as when it lives as a saprophyte, or takes food from the host as it is manufactured, in the case of parasites. The fungus of a lichen, however, has the

new duty of enveloping and protecting the alga so that the latter may increase in number and perform more effectively the task of manufacturing food for the fungus. A result of this is perhaps the reason for the development of the greatly varied and complex bodies of the higher lichens. The fungus supplies the alga with water and mineral salts and may also carry more or less of its carbon supply to it. The alga is protected in such a way that it is able to grow where it would be impossible to do so alone and its continued existence, through cell division, is assured, though fission goes on slowly as a rule, while reproduction by zoospores is entirely inhibited. It is self evident that the algal host cells, usually remote from the surface of the lichen, are in a much less favorable position for carrying on photosynthesis than when they are free. Sooner or later they are killed by parasitism or parasitism and saprophytism together.

It is this strange association of two unlike organisms, a fungus as master living as a parasite or a saprophyte upon an enslaved alga, which gives rise to the anomalous organisms called lichens, plants which differ markedly from either of their components.

The older botanists regarded lichens as one of the primary divisions of plants, a class equal in rank to any other. There was constant speculation over the origin of the green cells or gonidia as they were called, as they are so unlike the rest of the thallus. Lichenologists finally accepted the idea that they were formed from the colorless hyphæ and it was not until 1867, when Schwendener announced his "dual hypothesis," as it was dubbed, that the real nature of lichens began to be understood. His discoveries were bitterly denounced by systematic lichenologists who could not bear to see their favorites deprived of their important rank. Careful experiments with both constituents and with the spores produced by the fungal portion have at last established beyond question the truth of Schwendener's discoveries as to the twofold nature of lichens. Most botanists have accepted the theory that the association of alga and fungus is one of symbiosis or mutual helpfulness, and this is the view ordinarily presented in botanical texts. Here in the Philippines, as well as elsewhere in the tropics, we have remarkable and mutually beneficial associations between certain plants and ants, and in all parts of the world different kinds of animals or plants and animals dwell in relationships involving more or less mutual service. To merely list these would require a large amount of space, and many instances of more or less perfect symbiosis will be found in any elementary text. But the writer fails to find parallel cases among the lichens and agrees with Bruce Fink that morphologically "a lichen is a fungus, usually,

if not always, more or less parasitic during all or part of its life upon an algal host and also sustains a relation to an organic or inorganic substratum."

It therefore follows automatically that lichens should not be treated as a separate class but should be redistributed among the fungi by the systematist, thus doing away altogether with the class lichens. It is not at all likely that this will be done very soon as there are many difficulties in the way. Reproduction among lichens is peculiar; we are too ignorant of the fungal relationships of many lichens; while the interaction of alga and fungus has resulted in an organism and a mode of life which differ markedly from that of fungi, so that as a matter of convenience it is far easier to group lichens together than to have them scattered here and there among the fungi. These are some of the reasons why many botanists insist that lichens constitute a distinct class of fungi, if not indeed two.

Nearly all the fungi occurring in lichens belong to the *Ascomycetes,* though there are a few tropical species belonging to the *Basidiomycetes.* In most cases these fungi no longer live independently, that is, outside the lichen association and away from the algæ with which they have developed, though some live for years in their substrata without the algæ and become parasitic upon them later. The fungal constituent of most common lichens has been evolved from either the *Discomycetes* or the *Pyrenomycetes.* Such genera as *Peziza, Patellaria, Melaspilea, Phacidium, Chaetomium, Sordaria, Hysterium* and *Thelophora* are among those apparently closely related to the ancestors of the lichen fungi.

The algæ are of many kinds, though the great majority belong to a few families of green algæ or *Chlorophyceæ,* mainly to the *Protococcaceæ* and *Trentepohliaceæ;* there are also a few species belonging to the *Mycoideaceæ, Prasiolaceæ,* and *Cladophoraceæ,* occurring in lichens. The algal constituents of all gelatinous as well as many non-gelatinous lichens belong to the *Myxophyceæ* or blue-green algæ. They include various species of the *Chroococaceæ, Nostocaceæ, Rivulariaceæ, Stigonemaceæ* and *Scytonemaceæ.* Most of the algæ are readily recognizable as common, widespread species, but some of them, especially the blue-green forms, are often greatly modified so as to be unrecognizable by one who has only observed them under free living conditions. About one per cent. of the species of blue-green algæ are known to occur in lichens, the proportion of green algæ being very much smaller.

The fungal portion of ordinary lichens produces the characteristic fruiting body of the Discomycetes or Pyrenomycetes. The lichen fruit is known as an apothecium and of course has no connection

with and bears no relation to the algæ within the lichen. Some lichens are not known in a fruiting condition, while in a great many others the fruit is either usually or else always imperfect or sterile, the asci or thecæ never developing or forming spores. But many lichens do produce fertile spores which in time are thrown out to be distributed by the wind. Those alighting in favorable places readily germinate and in time may develop into lichens like the one from which they came, the hyphæ enveloping the proper kind of algæ from those growing on the substratum.

However, it is doubtful if the majority of lichens ever grow from spores even though they produce viable ones, but they propagate in an entirely different way. Upon the surface of the thallus of most lichens more or less minute powdery separable particles called soredia are formed, making up an amorphous powdery excrescence or a pustular body termed a soralium. Each individual soredium is composed of one or more algal cells characteristic of the particular lichens, entwined in lichen hyphæ or fungal threads. Each soredium is therefore a microscopic bit of lichen thallus and is a form of vegetative reproduction characteristic of these strange plants.

As the soredia are set free they become widely distributed by the wind and soon make their appearance on all suitable exposed substrata where they develop into the characteristic form of the particular species from which they came.

While propagation by soredia may be compared to ordinary vegetative reproduction by bulblets, gemmæ, budding, the breaking off of pieces of a mother plant or animal and other natural means, as well as by means of cuttings, it is only analogous and not homologous. Soredia are unique in that each minute speck or soredium includes two dissimilar organisms.

It is not at all surprising that this comparatively recent method which absolutely ensures the continuation of the composite life should have so largely superseded the uncertain method inherited from the fungal ancestor, since the latter leaves too much to chance.

Discussion of the development and structure of the apothecia, of sexual reproduction in a few lichens, of cephalodia, and the numerous structures and adaptations peculiar to lichens is here omitted.

At what period lichens originated we know not, for authentic records of fossil lichens earlier than the Cenozoic are doubtful, though it is possible that they existed in Mesozoic time.

Lichens did not have a single ancestor, but originated independently with numerous representatives of the two great groups

of fungi already named, and as previously stated these became associated with many different algæ belonging to two entirely different classes and several different orders. The evidence for the polyphyletic origin of lichens is beyond question, but though they have no common origin their manner of life is in all cases practically the same and they have therefore altered profoundly from the fungi from which they sprang. Their long life as compared to the ancestral fungi, their ability to persist through great climatic changes, their ability to endure successfully long periods of suspended activity and the formation of lichen acids which are not found in any other plants and are an excretion of the fungus, all serve to mark them as a distinct group.

There are some puzzling things about heredity in lichens. There is no inheritance in the sense in which that term is used in speaking of ordinary plants and animals. Not only do most lichens lack any form of sexual reproduction, but the spores produced can not transmit any lichen characters since they are produced by only one component of these weird plants. No chromosomes transmit the specific peculiarities of any given lichen, and the student of Mendelian inheritance can not point to anything comparable to the classic discoveries in sweet peas, guinea pigs, fruit flies, man and other organisms whose heritable characteristics are juggled about in the chromosomes of their germ cells. Yet lichens are among the most variable of organisms in spite of or perhaps because of their lack of germ plasm. Certainly here is a fertile field for the proponent of the inheritance of acquired characters to cultivate, using argument as his tool, as if argument ever settled anything, or for the students of eugenics by careful experiment to determine as nearly as possible just how lichens transmit heredity.

Although lichens are so variable, the same species, though with a multiplicity of varieties and forms, may occur over vast areas. But these changes, undoubtedly due to variations in light, heat, moisture and substrata, instead of ranging visibly about a fixed mean act differently in regions of geographic isolation. Here, apparently through control by a kind of orthogenesis or orthoselection, their variation goes on unimpeded in a given line until new species are produced. These new species may have become fixed or they may still be highly unstable and in process of splitting into two species having different habitats, *i. e.*, different substrata, as I have previously shown elsewhere. One great group of lichens, the *Cladonias*, is still in process of evolution as was long ago shown by Wainio, the great authority on this puzzling group, though it is perhaps no more variable than some well-known groups of flowering plants. About 40,000 species of lichens have been described, of which perhaps 15,000 may be called valid.

By the early systematists lichens were divided into three artificial groups according to their habit of growth. Crustaceous lichens are sufficiently defined by the name and pass by easy stages from the most inconspicuous forms up to the foliaceous or leafy lichens, or by another line into the fruticose, which may be erect and shrub-like or thread-like and pendulous. It follows then that a lichen may be of almost any shape, regular or irregular, which could be imagined in plants varying through such extremes as insignificant, barely visible dark stains and specks upon rocks or half buried in bark, or a group of minute pits in limestone, up to conspicuous leafy or bushy forms a foot or two across, great tangled masses of black hair, or enormous pendent gray growths reaching several yards in length.

Their color may vary from pure white to dead black, or brown, intense red, or bright yellow, but the commonest is a soft neutral sea green or gray green which lacks the vivid hue of ordinary green leaves. The color may be due to the algal constituent, as in the gelatinous lichens, to various pigments deposited in the walls of the fungal hyphæ, or to crystals of lichen acids excreted from the hyphæ and lying on the outer walls. A few rock lichens are tinged with iron rust due to iron salts in the substratum or water. Though many lichens are very beautiful, in most regions their colors are not at all conspicuous, but in some places, as in the mountains of the arid parts of the western United States, they often form the most brilliant feature of the landscape. Here one may see great boulders gaily splashed or huge cliffs made gorgeous by vermillion, orange, or vivid yellow crustaceous lichens. The spotted alders and many other trees in various parts of the world owe their characteristic mottled or variegated bark to the innumerable circular patches of pale or white lichens, while in the tropical rain forest great conspicuously colored, gray green, white, brown or even blood red areas of bark are the result of exuberant lichen growth.

One of the advantages of studying lichens is that collections may be made almost anywhere, though it must be admitted that great manufacturing districts are not favorable for their growth. But in general they occur from pole to pole and from sea level to the peaks of the loftiest mountains, wherever there is anything not covered permanently by ice or snow upon which they may alight and develop. On the ground, on rocks of all kinds, on the bark, leaves, exposed roots or dead wood of trees or any perennial plants, we may find them all over the world. One species grows upon the thallus of Polyporus and other bracket fungi, and one species is truly aquatic, growing on submerged rocks in mountain

streams. Many lichens swiftly avail themselves of fences, posts, wharves, barns and other unpainted wooden structures, and again others seem able to grow upon almost anything. One may find them, therefore, upon iron fences and the metal as well as the wooden parts of old farm machinery, on sun-bleached bones, dried dung, brick walls, old shoes, dead shells on the sea strand and even on ancient church windows.

A very few kinds grow upon the thallus of other lichens, but most of the species with this habit which have been described as lichens are really fungi, since they totally lack algæ.

No climate is too wet, too dry, too hot or too cold for lichens of some kind to flourish. The talus blocks of rhyolite exposed to the cloudless glare of the sun in a region with an annual rainfall of no more than 8 inches are covered with drought resistant lichens as closely aggregated as they can crowd, while the desert below sea level and with a rainfall of less than 2 inches has a plenitude of rock and earth lichens which thrive in a heat as great as earth affords. On the other hand the pinnacles of the great Puget Sound volcanoes or the sky-splitting peaks of the Alps are thickly crusted with layers of dark lichens or swathed in leathery, blizzard-defying *Gyrophoras*. From the farthest north land seen by Peary in his trip to the pole a bit of rock was sent me on which the lichens left no unexposed surface, while on many seashores rocks submerged at every tide are equally well covered by these strange plants. The lace lichen, *Ramalina reticulata,* largest and bulkiest of North American lichens, reaches its maximum development with a rainfall of about 16 inches, while in the forests of the outer coast range of Oregon or the mountains of Java, where the rainfall is measured with a yard stick, *Usnea longissima* justifies its name, attaining at times a length of 10 meters.

In the past most botanists and students of ecology have disregarded lichens in their observations, assuming without real investigation that they are worth nothing in this respect, but as a matter of fact they are probably not surpassed by any plants in value as true climatic indicators. From a study of the lichen flora alone of a given region one may learn all the important facts of its climate.

Lichens are, with trifling exceptions, perennial plants and a majority are of relatively slow growth and long life. While some, especially the large foliaceous species of regions with mild, humid climate, grow with great rapidity so that falling leaves and twigs are caught and embedded by their swiftly spreading tissues, others hardly change in appearance during the span of a human life. Many of the common, inconspicuous crustaceous and foliaceous

lichens become established and produce apothecia in from four to eight years, after which they may live for several times that before finally disappearing. As trees grow old and their bark roughens many lichens once conspicuous on them pass away because they are mechanically destroyed by the loss of epidermis and the hyperdevelopment of the cork layer in the bark.

Many lichens, such as the *Cladonias*, keep dying at the base and growing at the top much as the peat-forming *Sphagnum* mosses do, and like them may outlive the forest trees. Some of the crustaceous and foliaceous lichens die at the centre after a time, but continue to grow and spread at the circumference as long as there is any space left unoccupied, decade after decade seeing but little change. Since there is no vital growing point or area in a lichen, injury of one portion leaves the rest undamaged, and there is accordingly no limit to the age of many lichens. On huge open surfaces of rock one may observe vast circular mats or irregular sheets of *Parmelias* or enormous well-defined areas of *Lecanoras*, *Lecideas*, *Rhizocarpons* or other crustaceous genera which may apparently live, barring accident, as long as the cliffs stand.

From the remotest historical periods lichens have been valued and utilized by man. They were used for medicine by the Egyptians more than 3,000 years ago, while Pliny wrote, "As well in this wild kind as in planted plum trees of the hortyard, there is to be found a certain skinny gum, in Greek called Lichen, which hath a wonderful operation to cure the rhagadies or chaps." Down to the last half century a number of them were esteemed as valuable curatives but now only one of them, "Iceland moss," is still recognized by the U. S. Pharmacopoeia.

From the days when the merchants of Tyre carried her noted dyes and other valuable commodities to all the regions known to the inhabitants of the shores of the Mediterranean, down to the present, lichens have furnished many of the most valuable dyes. They were especially prized in northern countries, and it was not until the rise of the aniline dye industry that lichens became of secondary importance to the dyer. To-day they furnish the chief purple dyes for wool and silk and are the source of the valuable chemical color test for acids and alkalies—litmus.

In the frozen regions of Lapland, Siberia, Alaska and the Barren Grounds the chief vegetation over vast areas is *Cladonia rangiferina*, the noted "reindeer moss." This lichen is of the utmost economic importance to the Laplander and all the other peoples eastward to Hudson Bay, since upon it reindeer, caribou, deer and cattle depend for food during the long winter. In northern Sweden the people gather and store it for their cattle. In Iceland the islanders use "Iceland moss" in the same way.

While lichens contain no true starch or cellulose they contain a peculiar carbohydrate known as lichenin, which is an anhydride of galactose. Many lichens contain large amounts of lichenin and would be valuable food for man were it not that they also contain bitter acids which cause digestive trouble when eaten. By boiling or soaking with cooking soda or other weak alkalies so as to largely eliminate or neutralize the acids they may be eaten. "Iceland moss" is the best of these foods, and is used to a considerable extent in Iceland and the remoter districts of Norway and Sweden. Other lichens are used in various parts of the world, a noted one being a *Gyrophora* used in Japan and China since remote times. Another is *Lecanora esculenta,* a desert lichen which is supposed to have been the manna of the Israelites and which is known to the Arabs as "bread from heaven." Its food value, however, is very low.

It is in another capacity altogether that lichens are of the greatest importance, a field from which they will not be driven by advances in chemistry and which they will occupy as long as the existing conditions of life endure. Lichens are the pioneers in breaking down rock surfaces and in preparing the way for higher plants. In the rainy tropics blue-green algæ are the first to make their appearance upon freshly exposed surfaces, but elsewhere lichens are supreme in this difficult and extremely important rôle.

No rock is too hard or resistant for some kinds of lichens to attack. At first attaching themselves at microscopic crevices, they secrete acids which dissolve certain constituents so that the rock slowly disintegrates, the rhizoids of the lichen ever penetrating deeper and deeper. Crustaceous lichens may be followed by foliaceous or fruticose species, and these are in turn accompanied or succeeded by certain hardy mosses. Later, the way is easy for ferns and herbaceous seed plants and finally shrubs and trees to establish themselves. A few of the blue-green algæ are able to live in the water of hot springs, but no aerial plants are able to compete with lichens in carrying on life under the most extreme conditions of heat or cold. On the stoniest of blizzard-swept Arctic tundras lichens grow over vast areas to the exclusion of other vegetation, while as already shown deserts and mountain peaks have them in abundance when all other plants are lacking.

A few lichens are of importance because of the harm they do. Certain *Strigulas,* living on the evergreen leaves of tropical plants, are truly parasitic and damage somewhat coffee and other plants of economic importance. One often sees fruit trees with the limbs and twigs densely covered with leafy or shrubby lichens. I do

not believe that they are directly injurious, as long observation of orchards in California has failed to reveal any appreciable difference between trees heavily and lightly infested. But indirectly lichens are injurious upon orchard trees, since they harbor large quantities of more or less harmful insects. Lichens should therefore be removed from orchards by the use of either Bordeaux mixture or lye (caustic potash) solution.

Lastly, let us consider the benefits one may derive from a study of lichens. We may dismiss the probabilities of its leading to fortune and fame, but there can be no question that the true student of these unique plants has a greater opportunity for attaining health and strength than has almost any other devotee at the shrine of nature. Since lichens grow everywhere he will never be at a loss for material and he can gather them at any or all times of year, no matter what the weather. Sunshine, fog, rain, snow, it makes no difference, the lichen collector can take his fresh air constitutional and ride his hobby at the same time. Nor does he only tramp along through forest or prairie, or squat motionless for hours on the old stone ledges outcropping in some hillside pasture. Every atom of strength, agility and daring possessed by the most skillful mountaineers is needed when the lichenist seeks his treasures on Alpine crags among the glaciers or hangs in unstable equilibrium over the verge of some vast sea cliff whose foot is lost to view in a mass of boiling surf. One may even enjoy the climb up some sun-blistered precipice a thousand feet high, rejoicing in new treasures as he draws himself up from ledge to ledge, oblivious to the rattlesnakes who delight to take the sun in such places.

After the field work comes the long hours in one's den where with microscope and specimens one classifies his treasures, coordinates his field notes, and works out problems in ecology, geographical distribution and evolution. But whether he is on the apex of his favorite mountain gazing out over the world beneath while he rejoices in a successful day, or whether he is in his study wrestling with obstreperous specimens which refuse to be classified, he feels amply repaid for his time and effort. It is undoubtedly highly beneficial to man to do some things whose value cannot be estimated in dollars and cents.

The study of lichens satisfies our desire for strenuous muscular activity, often amid the most magnificent or awe-inspiring scenery, pleases our love of the beautiful, appeals to our desire to behold the incredible, and presents some of the most puzzling problems known in the living world to the students of geography, ecology, genetics and evolution.

PSYCHOLOGY APPLIED

By Professor W. V. BINGHAM

CARNEGIE INSTITUTE OF TECHNOLOGY

THIS is the story of an adventure in higher education. Few adventures are less spectacular and more hazardous than those which attempt to introduce something at once useful and new into collegiate conservatism, especially when emphasis in an established science is changed from the academic to the practical—for this was an experiment in directing psychology toward practical ends. These pages tell of the first formal establishment in an American institution of a department of applied psychology, an acknowledgment of the fact that the foundations, at least, of a worthy psycho-technology have been laid.

It is hardly thinkable that this experiment, begun in 1915, could at that time have had the cordial support of the typically traditional university. It had to originate in a youthful and unconventional institution whose frame-work was flexible and whose eyes were on the future rather than on the past. Such a school was Carnegie Institute of Technology. Therefore it is necessary first to describe the peculiar features of this institution, and then to sketch briefly the history of the organization there developed for attacking the problem of how to make psychology useful. On second thought, what could have been more natural or appropriate than that the technology of human behavior should have found a hospitable abiding place, not in a liberal arts college, but in an institution dedicated to the promotion of applied science?

One caution is necessary. No pretentious attempt was made to organize or develop the whole vast territory of applied psychology. The Division of Applied Psychology at Carnegie Institute of Technology has always sharply delimited its scope. It has not approached the problems of abnormal human behavior, criminology, mental deficiency, nor psychiatry. It has not duplicated the activities of the many agencies engaged in the study of childhood and of educational psychology in its applications to problems of the public schools. It has, instead, pointed its energies toward the exploration of promising but unoccupied areas.

This narrative gives, then, the account of an attempt begun seven years ago to direct scientific psychology into the service of

modern business and industry, as well as into channels of usefulness to the students, faculty and administration of this particular institute of higher vocational education.

I

My first glimpse of the institution which was to foster this experiment was on New Year's Day, 1915. Three days previously, at the close of one of the sessions of the American Psychological Association then meeting in Philadelphia, I had been introduced to a short businesslike man with a kindly but somewhat abrupt manner. His card bore the legend "A. A. Hamerschlag, Carnegie Institute of Technology." He wasted no words on preliminaries. "Carnegie Institute of Technology," he began, "is in Pittsburgh. I don't suppose you ever heard of it; but we have a flourishing young institution there. What are you planning to do this week-end, after the meetings? Won't you come and look us over, and then tell us what in your opinion psychology could do for such a technical institution?"

I had indeed heard of Carnegie Institute of Technology, although it was confused in my mind with the older and more famous parent institution across the ravine from it, namely, Carnegie Institute, which includes under one enormous roof the Pittsburgh Public Library, a museum of natural history, a museum of art, and a music auditorium. What I saw on that brief visit must here be recorded as a background for what comes later.

A sunny winter sky greeted me, not exactly what I had expected from the smoking furnaces of Pittsburgh. From the entrance to beautiful Schenley Park I saw a group of monumental public buildings, a civic center remote from the congestion of the business district. On the abrupt heights to the north rose the University of Pittsburgh; less than a mile from it, across a ravine to the south, Carnegie Institute of Technology; and, midway between, dominating the view, the expansive, globe-capped roof of Carnegie Institute.

The Institute of Technology was a revelation. Each of its four colleges occupied a building or group of buildings characteristic of the particular sorts of vocational training they housed.

The Engineering College, or School of Applied Sciences, as it was then called, had power plant and lecture halls, with spacious laboratories for instruction in the fundamental sciences and in civil, electrical, mechanical and chemical engineering. Far below the level of the campus, I saw the metallurgical and mining laboratories beneath which has since been hewn out a demonstration mine. Five stories above, were the headquarters of the department

of commercial engineering, where young men with the foundations of an engineering education were being trained to carry responsibility in the business management of production. Here was a substantial college of engineering, traditional in type, with a few unique features indicative of healthy vitality.

The woman's college, named for the founder's mother, Margaret Morrison Carnegie, reminded me at once of Simmons College, and of the School of Practical Arts at Columbia. Here were white-tiled laboratories of foods and cookery, studios for pottery and lace-making and jewelry, a model apartment, and rooms full of looms, dress-making mannikins, typewriters and accounting machines. If neither the household arts nor the secretarial courses appealed to the student, she might specialize, I was told, in social work and find ample laboratories in the Pittsburgh slums. All the courses, it seemed, were regular four-year college courses, differing from the typical liberal arts curriculum in their vocational specialization. A majority of the girls were fitting themselves to be teachers or public school supervisors of one or the other of these vocational subjects. Obviously, psychology was an essential part of their preparation.

In the Fine Arts College, at first called the School of Applied Design, were sumptuously housed the departments of architecture, painting and illustration, interior decoration, sculpture, music and dramatic art. Superficially nothing could have contrasted more sharply than these elegant studios with the stern laboratories and shops of the Engineering College opposite. The bond of identity lay in the vocational aim. Students pursuing courses in orchestra or in drama, no less than students of mechanics, were bent on fitting themselves to earn a livelihood. One respected the vision of the planners and founders of the institute for putting on a single campus these vocational schools of such contrasted character.

Perhaps the most characteristically distinctive of the four parts of the institution was the College of Industries—then called School of Applied Industries—occupying the original first building. Here one looks down corridors nearly an eighth of a mile in length, flanked on either hand by unit buildings in which are lecture halls and shops, high spacious rooms with equipment for teaching drafting, pattern-making, foundry practice, forge and heat-treatment, and machine shop—all the processes, in fact, which are basic in the machine production industries; in the building-construction industry—masonry, carpentry, plumbing, heating, ventilation, sheet-metal work and electrical installation; and in the printing industry—the fascinating processes of linotype, monotype and hand composition, press-work, multi-color printing and binding. This is not

a trade school, for it makes no pretense to develop manual proficiency and expertness to the point of trade mastery. Instead it does something better. It gives to the high school graduates who take its four-year Bachelor of Science courses some understanding of all the fundamental processes of the selected industry, so that on graduation the way is open to employment, not as a skilled tradesman, but as an assistant to an executive, with assurance that a ground-work has been laid for later success in a managerial or supervisory capacity. In this school also were young men fitting themselves to be teachers and supervisors of manual and industrial arts.

All four of the colleges, then, though differing enormously in appearance, in equipment, and in character of personnel, were alike in having definite vocational objectives that implied a combined technical and cultural training. From forty to sixty-five per cent. of the schedule of most of the students was devoted to studies of the more general or liberal sort, such as English, economics, history, mathematics and science. The happy mean was sought between broadly cultural and narrowly vocational extremes.

This, then, was the picture of Carnegie Institute of Technology when I first confronted the question put by President Hamerschlag as to the place and service of psychology in a technical institution. The schools had at that time been in existence barely ten years. The enrollment varied from about 250 in the woman's college to almost 500 in engineering. The total number of day students was 1,400. A somewhat larger number came to night school, nearly two thirds of these being in industries courses. Altogether, attendance numbered 3,200 students—2,600 men and 600 women; and of these, I estimated that a major fraction were looking forward toward careers in industrial management, social work, teaching, dramatic art, or some other field in which their success would in a measure depend upon their *ability to understand and influence people.* Here then was an obvious service psychology could render: to give to these students such instruction in psychology as would really enable them better to understand and control human behavior.

Students confronted by such a variety of opportunities faced a lively problem of vocational selection. Was it not fair to challenge contemporary psychology with the task of making itself helpful to these students in finding out their special talents and their limitations? This possibility of usefulness was the second to be mentioned in my report with recommendations to President Hamerschlag. I pointed out that as yet the psychological laboratory had made available almost nothing in the way

of adequate technique for helping young people to discover their aptitudes. Long and patient research would have to precede any considerable usefulness of psychology in this regard. But where could this research be better carried forward than in a vigorous young institution which offers on a single campus such varied types of vocational education?

The problem of admissions pointed toward a third possible utility of psychological methods. Could psychological examinations be incorporated as a part of the admissions procedure, to get supplementary information as to the likelihood that the applicant could undertake with profit the work of the Freshman year? I recommended no immediate use of these methods, but instead, a period of trial during which intelligence test-scores and personal interview ratings should be accumulated on all Freshmen, for determination of their predictive value in comparison with high school marks, principals' estimates, and ordinary entrance examination standings.

Still other uses for psychological technique were indicated. Data regarding traits, characteristics and differences in ability would be useful to deans and class-officers in advising students as to their methods of work and their problems of personal development; serviceable also to the placement bureau in getting information as to the type of position for which each senior was best fitted. Educational psychology, to be of use to prospective teachers of the manual, industrial and domestic arts, would call for experimental studies of learning, habit formation and the acquisition of skill. In the Fine Arts College there ought eventually to be a specialist in the psychology of art, who would use the methods of experiment to discover and teach principles underlying both art production and art appreciation. Finally, I urged appointment to the staff of a specialist in motion studies, work and fatigue, in relation to industrial efficiency.

In brief, my proposals grouped themselves around the outstanding problems of selection of students for admission, vocational and educational guidance, and placement at graduation, together with helping to give an insight into human nature to all students whose careers would require ability in understanding and controlling people. President Hamerschlag was well aware of the significance of these problems, and when after a brief interval, he asked me to assume direction of the proposed central department of applied psychology, he cautioned me that a difficult road lay ahead.

Psychology was far from being an unknown discipline in this technical institution before 1915. W. S. Libby taught general and

industrial psychology of the Münsterberg type to the manual arts students, and with one assistant had built up a laboratory with complete equipment for mental measurements of the sort described in Whipple's Manual; and in the Margaret Morrison school two instructors were conducting classes in educational psychology and the principles of teaching, for the young women who were preparing to become public school supervisors of domestic science and art. The new arrangement differed from the old in that there was now established a single central department for all four schools, a department with a fairly well-defined program of service to students, to faculty and to the administration. Service to business and industry, which was soon to become an outstanding feature of the program of the Division, had not yet been clearly visioned.

II

When the newly established Division began its activities in September, 1915, I had four associates: J. B. Miner, from the University of Minnesota; J. L. Zerbe and Katherine Murdock, who had been instructors in the Industries school and the Margaret Morrison Carnegie College for Women; and L.L. Thurstone, a graduate student from Angell's laboratory at Chicago. Thurstone took as his province the learning process and soon initiated experiments in cooperation with the linotype instructors in the printing department. Miss Murdock began the preparation of a scale for measuring merit in sewing, a step which seemed essential as a preliminary to research on the relative worth of rival methods of instruction and training in domestic art. Zerbe continued some studies he had been making on the distribution of grades given in class-room and shop courses. Miner took the problem of getting for the Placement Bureau dependable ratings on seniors in non-intellectual traits. He also examined students individually, and devoted much time to diagnosis and training of two stutterers and of other students who had serious but remediable handicaps of personality. All of us shared in the development and standardization of group tests, for several of which norms were accumulated and reduced to percentile form. Among these group tests were some devised by Thurstone for the purpose of measuring ability to deal with ideas of space relations, an ability without which it would seem to be difficult for a student to succeed in such subjects as descriptive geometry, pattern-making, sheet-metal work, costume design or architecture.

Some equipment was installed, including a Seashore tonoscope for vocational examining in music, an Einthoven galvanometer for research in fatigue, and several tachistoscopes.

The first vocational guidance problem was referred to me by

the Dean of the Industries faculty. A student did not know whether to choose the career of plumber or pianist! The boy was in the building construction course at the time, but restive. He had grown up in a small Pennsylvania town where his father was a dealer in plumbing supplies. He was extremely fond of music and had had a year or two of instruction on the piano. Ought he to drop his present course and aim at becoming the virtuoso of his dreams? I did the best I could to test his musical talent, with such few norms as were then at hand. I secured the judgment and advice of members of our music faculty. And then I had to tell him that as far as we could learn, his chances of becoming a distinguished pianist were nil. He might, in due time, achieve to a position in a café orchestra, but nothing more. In spite of our recommendations, the boy left school to study music under a private tutor, and at last accounts was earning a precarious livelihood giving piano lessons to children. Whether he would have been more happy and useful as a master plumber, who shall say?

The first problem referred to us by the dean of the college for women was that of two advanced students of costume design who were on the verge of failure and elimination. How were we to diagnose their difficulties? We did our best, by personal interview, intelligence examinations and such tests of special aptitude as we could devise. Neither of the girls was stupid; both ranked in intelligence among the middle third of college students. But when I gave them tasks like the reversed clock-hand test and the folded-paper test of the Binet series, one solved them promptly while the other was at a complete loss. The difficulty of the former girl with her school work was one not of ability, but of character. She thought her teachers were unfair and would not apply herself. But with the girl who failed consistently in the form tests, there was little question but that she was deficient in a special ability which is essential in any such subject as costume design, namely, the ability to deal with space ideas. The marvel is that she could have reached the junior year without having become aware of this lack. Thanks in part to the report we were able to give her Dean, she was not dropped from the school, but was transferred to the social work department, where she developed an unsuspected aptitude for work with children.

These are typical of our first tentative moves in the direction of vocational guidance procedures for college students. We yet have far to travel on this road, but appreciable advance has been made since 1915, as is evidenced, for example, by the Thurstone tests for engineering aptitude, with norms gathered from many thousand freshmen.

Miner's Analysis of Work Interests blank is typical of another sort of vocational guidance technique, on which research has been focused since the very beginning of the Division.

Kate Gordon's tests of taste in color and in design and her tests of dramatic insight, on which she worked beginning in 1916 when she first joined our staff, illustrate the effort to measure aptitudes in art activities.

A glance at the annual report of the Division for the first year shows that a start had been made on nearly all of the main portions of the original program. We had centralized in one department the teaching of all psychology and education courses given in the four colleges—a type of departmental organization which has since been adopted for English, mathematics, history, economics and other general or cultural subjects which are essential to any technological curriculum. In research, we had resolutely kept away from certain inviting territories in applied psychology, such as the psychology of advertising and the examination of mentally defective children, because these were being actively cultivated elsewhere. Instead, we were working out methods of helping the deans determine the qualifications of students at entrance, of helping students decide most wisely what careers to choose, and of cooperating with the Placement Bureau in getting information regarding the lines of work for which the seniors seeking positions are best adapted. We were striving to make psychology practical in educational and vocational guidance. In the next section will be told how our efforts came to be directed also toward business and industrial problems of personnel selection.

These, then, were the beginnings made at Carnegie Institute of Technology to erect upon the academic science of psychology a psycho-technology.

III

I had been only a few weeks in Pittsburgh when President Hamerschlag introduced me to a business man of exceptional leadership, Edward A. Woods. Mr. Woods is the district representative of one of the great life insurance companies and is nationally reputed to have the most productive of all life insurance agencies. He was urging that Carnegie Institute of Technology ought to teach courses in salesmanship!

"What is the matter with the courses already offered by the various institutes of salesmanship?" I asked.

"They are all right, but they don't get very far."

"You wouldn't want us, then, to duplicate such courses?"

"No."

"Then before entering this field, we ought to find out more than is now known about selling and salesmen. We should have to learn the difference between successful and relatively unsuccessful salesmen. We ought to study their talents, their aptitudes, their traits, their personal histories, their duties. We should need to gather information as to the potency of incentives and appeals to sales effort and the best methods of selection, development and supervision of salesmen."

President Hamerschlag pointed out that research of the kind required would call for joint effort on the part of a staff of research workers and a group of representative cooperating businesses. And the results might be slow in coming. Patience would be required.

"Do you think the firms that are interested in improving the general quality of their sales force are enough concerned about it to invest real money and several years of cooperation?"

Mr. Woods thought they would be. He cited statistics from sales organizations of national scope to show how enormous is the annual financial loss to business and to the public through employment of new salesmen who eventually fail to make good.

The upshot of the interview was that I prepared a plan for a research bureau to be sponsored and housed by Carnegie Institute of Technology and to be supported by a group of thirty cooperating industrial and business houses, each contributing $500 annually for five years toward the research budget. This budget was underwritten personally by Mr. Woods and two of his friends, Mr. H. J. Heinz, the venerable manufacturer of food products, and Mr. Norval A. Hawkins of Detroit, at that time manager of sales for the Ford automobile. They in turn, with President Hamerschlag's help, secured the cooperation and support of other concerns of national scope, such as Burroughs Adding Machine, Carnegie Steel, Westinghouse Electric, Armstrong Cork, American Multigraph, Packard Automobile and several of the great life insurance companies.

The founding of this Bureau of Salesmanship Research was in many ways a pioneer undertaking. We found little precedent for the proposed form of cooperation between college and business. We aimed to attack with the tools of psychological and statistical measurement a group of problems that had not previously been admitted within the pale of scientific inquiry. It was hard to find men with training adequate to such work, who could be secured for the Bureau staff.

Looking back, now, seven years, it is astonishing to recall the dearth of psychologists with an interest in business problems.

Only two or three in all America had at that time exhibited a competence in practical business psychology which would warrant us in expecting them successfully to direct such an undertaking as the new Bureau. We were fortunate in persuading Northwestern University to give us the loan of Walter Dill Scott, who came to Pittsburgh in June, 1916, as the first American "Professor of Applied Psychology" and Director of the Bureau of Salesmanship Research. Scott's connection with this division during the following three years brought it prestige. His scientific acumen, his exceptional personal leadership and his shrewd, sensible insight into practical business affairs were invaluable aids in the movement to apply psychology to problems of commerce.

The research problem for that first year was the selection of salesmen. Visits to sales managers of the cooperating concerns helped to define the line of attack. The practical experience of these executives was pooled, their methods analyzed and compared. Some experiments in actual selection were tried. The work of the seminar during that year, 1916-17, eventuated in a volume of "Aids in Selecting Salesmen." It included a model application form or personal history blank; an ingenious and compact model letter of reference to former employers; a set of aids in personal interview, designed to focus the interviewer's attention on essential points and to quantify his judgments on those points; and a battery of mental tests with full instructions for giving and scoring. These various "Aids" were issued to the member companies with the expectation that they would be used in employing new salesmen until sufficient data had been accumulated for checking their worth against the criterion of relative sales success.

IV

Then came the war.

The best elements of these group intelligence tests were incorporated with similar materials of Otis, Terman, Yerkes, Wells and others to make up Army Alpha.

The interviewer's score sheets became the "Scott Rating Scale" for selecting and rating officers and officer candidates.

The personal history record, greatly metamorphosed, became the C. C. P. Qualification Card, by aid of which three million men were classified for military purposes according to their occupational, educational and personal traits.

Practically the entire staff of the Bureau of Salesmanship Research and several other members of our Division of Applied Psychology found their best opportunity for usefulness in military psychology or in army personnel work. In the spring of 1917,

Whipple and I served on the committee of seven which prepared the first psychological examination methods for army use. A few weeks later Scott became director and I the executive secretary of the Committee on Classification of Personnel in the Army, and under Secretary Baker's direction, assembled the group of psychologists and employment executives who devised and administered the army personnel system. The first year of the bureau proved to have been an ideal preparation, a rehearsal for the enormous task of military classification and assignment.

If peace had been a preparation for war, war no less prepared for peace. The lessons of experience in dealing with all kinds of men in the army later proved valuable in the renewed task of applying scientific methods to problems of personnel in business and industry.

Selection, classification and development of clerical and executive personnel was demanded, as well as the study of salesmen. The bureau had been piloted during the last year of the war by G. M. Whipple as acting director. He had continued to gather data on salesmen and had initiated investigations of methods of training and supervision. Scott returned from Washington in the spring of 1919, but he shortly relinquished to C. S. Yoakum the direction of the bureau which then took the new name, Bureau of Personnel Research, because its problems and activities had far outrun the original definition of scope. Some of the original cooperating firms withdrew support; others doubled their annual fees, so that the total budget was increased; and still other firms, interested in specific problems, entered into special contracts with the bureau for more research and consultation than a straight membership fee could provide.

The war had wrecked the bureau staff, and Yoakum had to build a new organization, to salvage what he could of the earlier research, and to begin again accumulating data from which dependable inferences could be drawn as to the relative value of various items of information and test data in personnel selection. To-day he can speak with authority on the utilities and the limitations of different methods of selection, of classification and of supervision; and what is more valuable still, he commands the technique of research on these problems. The reports and service bulletins which he and his associates have prepared contain a mine of methods and principles. Mention of only one or two studies must serve here as typical examples.

In the first year of the bureau an experiment with a group of forty salesmen of one of the cooperating companies had yielded

the dismaying results that success in selling for that concern had a correlation with intelligence test scores of zero! There was no relation whatever between demonstrated ability as measured by amount of sales and intelligence as measured by the tests. The results appeared to be a severe indictment of the tests as measures of intelligence. When Yoakum, two years later, first examined these disconcerting data he knew from army experience that the psychological tests had real validity as measures of intelligence; and he solved the riddle. He first took the same data and computed the correlation between intelligence test scores and length of experience with the company. The coefficient was not zero. It was negative, —.40. The brighter the salesman, the quicker, as a general rule, he left the employ of that concern. He gave fresh examinations to seventy-three salesmen in the same company. The correlation between intelligence and length of service was —.46! By accompanying typical salesmen throughout the day, it was ascertained that their work was largely of the routine, order-taking sort. The pay was not large. The chances for promotion were slight. Under these conditions only the more stolid men were content to remain with the company long enough to get valuable experience and build up a creditable sales record. In such circumstances it was possible to determine an upper limit as well as a lower limit on the intelligence scale. Within this range the chances that an applicant for a position with this concern will make good are large. Below this zone he will probably fail for lack of ability. Above it, the chances are that he will not remain in the employ of the company long enough to make a success. The psychological tests were, after all, valid measures of intelligence. The need had been for a scientific determination of the range of their utility. The task of the Bureau of Personnel Research, typical of the aim of the entire Division of Applied Psychology, has been to mingle scientific method and business sense.

The readiness of business men to join hands with a technical institution in such cooperative research undertakings is well expressed in terms of what they are willing to pay toward its maintenance. This cooperation has been increasingly liberal. Little did I think when first we talked in 1916 about support for a research bureau that within a period of six years the Division of Applied Psychology would receive from such sources for its current expenses a total of about $237,000.00. Nor could I then picture clearly the succession of fine, loyal men and women of the faculty whose industry and talent have multiplied for science, for commerce and for society the value of that sum.

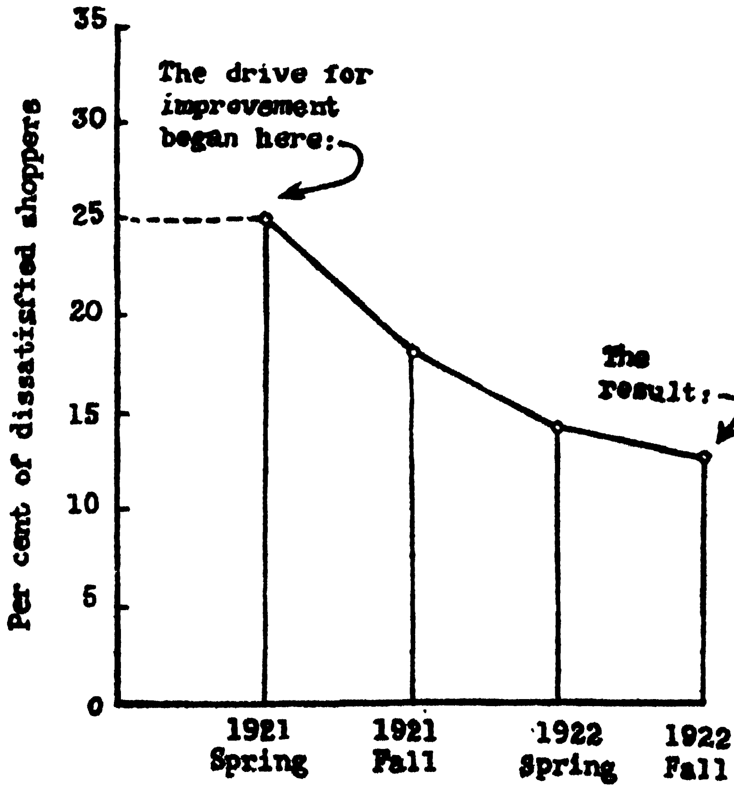
V

Cooperation of business and education on personnel research proved to be a fertile idea. The first of the bureaus soon had a lusty offspring, the Research Bureau for Retail Training.

Among the original members of the Bureau of Salesmanship Research was Edgar J. Kaufmann, a major executive of the largest department store in Pittsburgh. He quickly saw that the general plan of the bureau was sound, but that with its meagre funds and its wide variety of contributing members, it would make but slow progress on the problems which most interested him, namely, those of personnel and training in retail salesmanship. He secured the cooperation of six other Pittsburgh stores, and with them undertook, in 1917, to provide $32,000 annually for a five-year period, for the support of a new bureau to be devoted exclusively to problems of employment, supervision and training in the retail field. The detailed plans were worked out by Miner, who directed the enterprise during its first critical year. Then, in 1918, W. W. Charters came from Illinois to take charge of the bureau, which, if its story were to be told with full account of its achievements, would demand a volume in itself. It has applied the methods of science to the study of store personnel problems of employment, training and supervision. It has prepared training manuals, merchandise manuals, employment tests and specific procedures for correcting defects of sales personality and of supervision. It has worked out retail salesmanship courses for high school use. It has annually trained a small group of graduate students to become either educational directors or store research workers. This bureau has combined psychological insight, research methods and practical business judgment to the end that the public might have an increasingly intelligent and courteous department-store service. Its publications, extensively distributed, are in a small but tangible way modifying for the better the retail sales service of the nation.

How is a business man to know whether this kind of cooperative research pays? The Pittsburgh stores found out by measuring the decrease in the proportion of dissatisfied customers. One of these stores makes on the average about 30,000 sales a day. Inevitably a certain fraction of these purchasers leave the store displeased. The ratio of satisfied to dissatisfied customers has been found by the device of service shopping. Numbers of men and women—mostly women—have been engaged from time to time to make actual purchases of linens, dishes, cloaks and other articles needed, and then later report in detail on the kind of service they have had. The courtesy and interest shown by the sales woman, her knowledge of stock, her personal appearance, her helpfulness,

are all noted. The transaction as a whole, including promptness of delivery, is rated as satisfactory or unsatisfactory. The chart shows what happened in one large store where such service shoppings have been made frequently, beginning in the spring of 1921. Since the store has adopted research bureau methods for increasing courtesy and competence, the proportion of dissatisfied customers has considerably and consistently fallen—an improvement which registers, not only on the balance sheet of the business, but in the approval of the buying public.



MEASURING THE VALUE OF RESEARCH

One store has in less than two years' time cut in half the percentage of dissatisfied customers through improvements in training its salespeople to be courteous and helpful. The training methods were developed and installed by the Research Bureau for Retail Training.

VI

The initiation of the department of Educational Research dates from 1918. Whipple had come on from the University of Illinois for half the year as acting director of the Bureau of Salesmanship Research in Scott's absence; and the following year he resigned

entirely his connection at Illinois and came to Pittsburgh as Professor of Educational Research. His function was not that of the typical student of public school problems. Instead he was to concentrate on problems of higher technical education as they became pressing from time to time in our own institution—problems of admissions, of curricula, of methods of instruction, of administration. His first task was to assemble for the benefit of the entire faculty an exhibit of new examination methods and other teaching aids designed to lighten the instructor's load. Obviously, one man and an assistant could do only a small fraction of the research proposed by the President or pointed out as important by faculty committees· but the rest of us in the division gave him our cooperation. Thurstone took the admissions problems; Miner, the marking system; Charters helped on curriculum research, and also conducted a seminar for inexperienced instructors in methods of college teaching. I worked mainly on administrative problems. E. K. Strong, Jr., coming in 1919 when Whipple went to the University of Michigan, made extensive job analyses of the manager's functions in machine production, building construction and printing concerns, to get light on problems of curricula in the Industries College which trains for executive positions in those industries; and later he undertook research on the study-methods of Freshmen.

One specific task of curriculum building grew out of the work of the Bureau of Personnel Research. In 1919 the original demand was renewed for a short course to train salesmen of life insurance. If such a course were to be prepared and offered, Winslow Russell of Hartford and other life insurance executives would undertake to see that the Institute did not suffer any financial loss. John A. Stevenson, secretary of the University of Illinois School of Education, and Griffin M. Lovelace of the Connecticut Mutual of Hartford were chosen to prepare with Strong's help this curriculum and initiate the course of instruction. Some time the story must be recorded of how, through many months of intensive research, these men organized in detail the five courses which together were to constitute the three months' curriculum. Field practice in actual soliciting, under direction, was introduced as an integral part of the program. This practical experience had to be carefully planned to dove-tail day by day with the lecture and textbook materials of class instruction.

This novel experiment in intensive adult vocational education was a success from the start. Whereas it was quite generally believed in life insurance circles three years ago that it is futile to try by means of a course of instruction to teach salesmen the principles, functions and practice of life insurance, to-day the idea is

widely accepted that a salesman should have some such systematic instruction before he is permitted to offer to prospective customers his counsel on the purchase of life insurance. The American public should be grateful to this course for what it has done toward permanently raising the standard of competence and of professional and ethical attitude among salesmen of life insurance.

For two years my own research interests have included a group of problems in the applied psychology of music. Thomas A. Edison, having invested large sums of money and a vast deal of ingenuity in bringing his favorite invention, the phonograph, to its present degree of perfection, asked us to find out more about the effects of different kinds of phonographic music on the listener. With equipment and assistants which he has supplied, we have classified six hundred selections according to their observed effects on mood, and have carried through a number of experiments on the influence of different types of selection on efficiency in practical activities.

VII

This narrative of origins must hurry past the tempting themes of the years of gradual growth and give in conclusion a cross-section view of the division at the culmination of its sixth year.

Psychology had been brought into the service of students, instructors and administration. Its principles and methods were being applied to vocational education, to educational administration, to commerce and industry.

One department had become seven: The Department of Psychology, the Department of Personnel Administration, the Department of Vocational Education, the Department of Educational Research, the Bureau of Personnel Research, the Research Bureau for Retail Training and the School of Life Insurance Salesmanship. The staff had grown to a total of nine women and men of professorial rank, nine instructors and seven statistical and clerical assistants. A majority of these were financed through funds contributed by business concerns and devoted their first attention to research on applied problems. Out of a total of sixty-five graduate students who since the initiation of the division had been attracted here by the atmosphere of practical science, eight had earned the Master's degree, and two the doctorate. Three were occupying university positions as instructors in applied psychology. Most of the others were in business concerns as research assistants or personnel executives, and the demand for able young men with this type of training had far outrun the supply.

Along with the research work of the Bureaus the main duties

of the staff continued to be to care for the various undergraduate classes in introductory psychology, social, educational and industrial psychology, esthetics, personnel management, advertising and selling. At the same time a small group of graduate students were in training for research and for executive positions in the personnel and training departments of large business and industrial concerns. Their instruction included a grounding in systematic psychology, theory and practice of mental measurement, statistical technique, personnel administration, research methods and such specialized opportunities as are offered from time to time in the several seminars.

The best introduction for a graduate student who wants to fit himself for a career in applied psychology is, we are convinced, not a series of courses in applied psychology, but rigorous instruction in the fundamentals of pure psychology and scientific method, under instructors who are in touch with live problems in both the pure and the applied science, and who can guide the student in his own first approaches toward research on problems of significance to both psychology and industry.

And so a two-fold purpose has guided our plans: to make psychology useful, but also to advance psychology as a science. In studying the effects of music on mood, or the classification of clerical workers according to responsibility, or the teaching of department store clerks to be courteous, or the prediction of student success in engineering, or the differentiation of graduate engineers into those who should be trained as salesmen and those who would succeed better as designers—whatever the nature of the inquiry, we have aimed to solve if possible the immediate practical issue and also to accumulate insight into the psychological principles underlying the observed behavior.

We have found traditional psychology best prepared to be of service, to industry as well as to education, in those sections which treat of the intellect and of learning. But in its treatment of the more permanent trends of human character and action, the psychology of to-day is inadequate. Its attention has hitherto been focused largely upon the structure and nature of the momentary psychosis. Relatively much too small a portion of a typical treatise on psychology has been devoted to exposition of the fundamental impulses, the enduring interests, motives and drives which are at the root of conduct. Too little study has been given to personality, disposition and character and to the emotions and their actual functioning in behavior. Six years' experience in the Division of Applied Psychology made acute the inadequacy of current psychology to explain illuminatingly these non-intellectual

processes which, after all, constitute the most significant phases of mental life.

It is one of our ambitions ultimately to be of some help to systematic psychology in meeting these inadequacies. We have already amassed a large amount of illustrative material, actual recorded instances of behavior in the every-day human relationships of supervisor and employee, of sales person and customer, of instructor and student, a study and classification of which is yielding fresh generalizations for the psychology of habit, impulse, emotion and will. The Division of Applied Psychology has found its justification not only in such service as it has been able to render to industry and education in applying what psychological knowledge was available in 1915; it has also made some progress toward achievement of its secondary aim—that of reinterpreting systematic psychology in the light of new information gleaned here from the applied field.

With the beginning of the year 1921-22 the Division entered into another stage of its history. The name, Division of Applied Psychology, was changed to Division of Cooperative Research, its functions to include the promotion of research in other sciences and technologies as well as in psychology. With this broadened task, however, the present article is not concerned. We need only note that the basic aims remain the same, those of increasing scientific knowledge and of making science useful. The purpose has been and is to serve this industrial community just so far as space, equipment and personnel permit; and at the same time help in bringing to our students that vitality of instruction which comes from teachers in close contact with real present problems of industry.

This adventure in academic organization is still too young to have found as yet many imitators. I know of but one other department bearing the name of applied psychology. Although in other institutions cooperation between science and business has been carried to a high degree of perfection in chemistry, physics, geology and other sciences applied to the improvement of industrial methods, research in psychology for the interest of business is as yet in its infancy. Parts of the Carnegie program have, however, found a ready acceptance here and there. Courses in the psychology of business and in personnel administration are offered under one caption or another in many universities and institutes of technology. The Thurstone tests of engineering aptitude have been used in a score of engineering schools. The brief curriculum for training life insurance salesmen has been taken over in detail by four universities, east and west. In several institutions of

higher learning, business research bureaus have been created by means of which commercial concerns are enabled to cooperate under disinterested educational supervision.

But perhaps only in Pittsburgh, sooty, dynamic center of industrial America, could this movement toward the development of a useful, a practical psychology have found such full expression.

This article has described a concrete attempt to make use of psychology. A vast field of promise, of which these pages hint at a fraction only, lies open to any institution which sets out upon similar adventures in the realm of psychology applied.

SOCIAL LIFE AMONG THE INSECTS[1]

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Lecture VI. The Termites, or "White Ants"

THE twenty-one independent social organizations which I have reviewed in the preceding lectures all belong to two natural orders, the Coleoptera and the Hymenoptera, insects so complex and specialized in structure and in their postembryonic development that they are placed by entomologists among the most advanced and recently evolved groups. In order to complete our survey and include the three remaining types of social life, we shall have to turn back to the opposite end of our classification, to the most ancient and primitive orders, the Dermaptera, Embidaria and Isoptera, insects that do not hatch from the egg as specialized and often aberrant and maggot-like larvæ, but as forms very much like the adults, except that they lack wings. Owing to their archaic character, it would have been more natural to deal with these three orders in the first lecture, but I have reserved them till the end because one of them, the Isoptera, or termites, has a social organization in some respects even more highly developed than that of the Hymenoptera and are best understood by comparison with the ants. The two other orders, the Dermaptera and Embidaria, have a very feeble or rudimental social organization and may, therefore, be treated very briefly. They are interesting mainly as showing that social tendencies must have made their appearance very early in the ancestral history of the insects and as indicating that such tendencies may have been rather prevalent among the ancient Carboniferous orders.

The Dermaptera, or earwigs, are peculiar elongate insects, provided with strong forceps at the posterior end of the body, very short, leathery fore wings, or elytra and singular fan-shaped hind wings. Most of the species are tropical and vegetarian, though some are more or less omnivorous or even predatory. The forceps, which differ in the two sexes, are used both in defense and in seizing the prey. We have very few native species of Dermaptera. The common European earwig, *Forficula auricularia*, has been recently introduced into Newport, R. I., where it has become a serious

[1] Lowell Lectures.

pest in gardens and houses, and another large European form, the maritime earwig, *Anisolabis maritima,* is now common along our coast from Maine to Long Island. You will find it abundant at Revere Beach at or near high water mark under the drift wood and débris tossed up by the waves. A very small native species, *Labia minor*, is common in manure heaps, mushrooms, etc.

The earwigs may be included among the subsocial insects because the female carefully guards, rearranges and licks her eggs and even remains with the young for a short time after they hatch. The habits of the common European species have been repeatedly described. The German entomologist Frisch, as early as 1730 and the more eminent Swedish entomologist DeGeer in 1773 recorded the fact that the female cares for her eggs and young. The following more detailed observations on the maritime earwig were published by Bennett in 1904: "When about to lay her eggs the female would make a little chamber for herself in the ground about half an inch deep and one or one and one quarter inches wide. This was hollowed out beneath a log or some other object that rested on the ground. In making this chamber she carried the earth out in her mouthparts, as already suggested, a little at a time, just as an ant would do. She never seemed to use her forceps for either digging or carrying the earth. The chamber is made perfectly clean; no sticks or bits of wood or pebbles are allowed by the more careful females to remain inside. Here she deposits her eggs. In the chamber of one wild earwig I counted about ninety eggs, but none of those I have had in captivity laid quite so many at a time. some laying only twenty-five or less. Immediately after the eggs were laid the female picked them up in her mouthparts. one at a time, and wiped them all over. It looked indeed, as if she rolled them in her mouth. However that may be, when the process is over the eggs are all clean and glossy. Then she places them in a neat pile and stands guard over them. Whether or not it be true with the wild insect, some of the females I have kept for observation have, before their eggs were hatched, moved them all several times from place to place, carrying them one at a time. Some of my earwigs refused to touch food of any kind, so far as I could see, from the time they laid their eggs until the young were hatched, while others would leave their eggs at times to get something to eat. Several times the females, after caring for their eggs a while, have eaten them. I have reason to think, however, that in nearly every case the eggs had already spoiled or dried up before this occurred. The females continued to guard their young for a few days after they were hatched. When, however, they had once left her to seek food for themselves, they could not safely

return lest she should endeavor to eat them. One earwig which I kept in confinement deposited four fairly large batches of eggs in one summer."

The Embidaria (Fig. 93) are a very small order of some 11 genera and 56 described species, confined to the tropics and of an even more archaic habitus than the earwigs. They are rare or local and live in small colonies in peculiar silken webs which they spin in cavities of the soil under stones or on the bark of living trees. The females are always wingless, but the males in some species are dimorphic, one form having well-developed wings, the other being wingless. They feed on vegetable substances. The webs (Fig. 93*c*) consist of tubular, branching or anastomosing galleries and are spun with the fore feet which have peculiar silk-glands in their enlarged metatarsal joints. I have seen these webs in great numbers on the bark of rubber trees in the island of Trinidad and of various forest trees in Guatemala.

The habits of the Embidaria have been studied by Grassi and Sandias, de Saussure, Melander, Perkins, Friederichs, Kusnezov

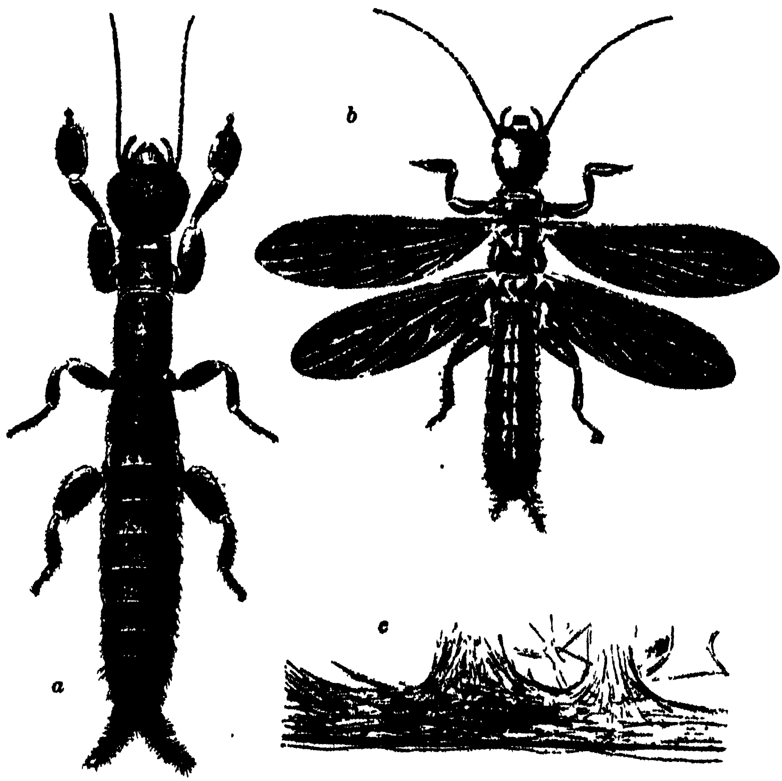

FIG. 93
a, *Embia major* of India, female; *b*, male. (After A. D. Imms.) *c*, *Anisembia texana* of Texas, female in web. (After A. L. Melander.)

and Imms, and we possess two excellent treatises on the morphology and classification of the group by Verhoeff and Krauss. Imms has recently discovered under stones in the Himalayas a large species, *Embia major* (Fig. 93*a* and *b*), nearly an inch long, and has published a full account of its habits. He summarizes his observations on the care of the young as follows: "Maternal care on behalf of the ova and young larvæ is strongly exhibited by the females, in very much the same manner as has been long known to occur among the Dermaptera from the observations of Frisch, DeGeer, Xambeu, Green and others. The female *Embia major* shows very marked solicitude for the welfare of her offspring after her first few eggs have been deposited. She takes up her position in close proximity to the ova and usually concealing them, so far as possible, by means of her body. If alarmed and driven away, she returns sooner or later to take up the same attitude. When the young larvæ are hatched they remain around the parent female, who conceals them, so far as she is able, by means of her body, very much after the same manner as a hen guarding her brood of chickens. A female and her brood were kept in a small glass trough and observed daily living in intimate association. When separated from the parent the larvæ were observed the next day to have regained their former position. As the larvæ approach their second stage in growth, they exhibit a tendency to wander away from the female and construct small tunnels for themselves. They are markedly social, the whole of a brood living together within a complex silken meshwork of tubes."

The resemblances in the habits of the Dermaptera and Embidaria will be sufficiently clear from the foregoing remarks. In both orders there is a feeble tendency to a social organization like that of the dung-beetles considered in my first lecture. It should be noted that the female Dermapteron and Embidarian live for several months after mating, so that in their cases also the first prerequisite for an extension of maternal care of the offspring is realized.

In the Isoptera, or termites, we encounter a social organization of unusual interest, both because it is so elaborate, though exhibited by insects of a very primitive anatomical structure, and because it parallels in so many of its features the social organization of the most highly specialized Hymenoptera. It is as if we had found, when Australia was first explored, the kangaroos and opossums enjoying a social organization like that of man.

The study of the termites began in the eighteenth century with Koenig, who described some of the Indian species in 1779, and

Smeathman, who in 1781 published an excellent paper on some West African species. During the nineteenth century the group attracted few investigators. In 1855-60 Hagen, who was later curator of entomology at our Agassiz Museum in Cambridge, published an important monograph, and Lespès in 1856, Fritz Müller in the seventies (1871-1875), Grassi and Sandias and Haviland at the close of the century (1897-98) gave us valuable accounts of the habits and development of the South European, South American and paleotropical species. During the past twenty years, however, there has been a veritable "boom" in the investigation of these insects. A long list of able workers—Wasmann, Desneux, Sjöstedt, Holmgren, Silvestri, Escherich, Bugnion, von Rosen, Tragaordh, Feytaud, Petch, Imms, Nassonov and Uichanco, in the old World, and Andrews, Knower, Heath, Banks, Snyder, Emerson and Miss Thompson in the United States—have added greatly to our knowledge of the termites. This speeding up of investigation may be gauged by the number of species brought to light since the time of Smeathman. In the early nineteenth century only a few were known, in 1858 Hagen cited 60 forms, by 1904 Desneux was able to list 343 in the "Genera Insectorum," and at the present time the number of described species must be over 1,000. No doubt the greater accessibility of tropical faunas during the past two decades and the increase in the number of well-trained entomologists adequately accounts for this extensive and intensive investigation, for the termites are nearly all tropical or subtropical insects, and being soft-bodied and rather unattractive have never appealed to the amateur who delights in collections of beautiful pinned specimens. We have only 38 species of termites in the United States and only two of them reach the latitude of Boston.

The recent ransacking of the tropics by the specialists above mentioned has led to a much more satisfactory classification of the Isoptera. According to the latest and best arrangement, devised by Nils Holmgren, the order may be naturally divided into four families, the Mastotermitidæ, Protermitidæ, Mesotermitidæ and Metatermitidæ. All the species are social, but the four families show a progressive development in the order mentioned and in both structure and habits, from primitive and generalized to more advanced and specialized forms. I shall refrain from annoying you with taxonomic details, but I must dwell for a moment on the Mastotermitidæ, which have the same interest for the termitologist that *Pithecanthropus erectus* has for the anthropologist. The family Mastotermitidæ was established by Froggatt for a single species, *Mastotermes darwiniensis*, from Northern Australia. A study of its structure shows that it combines characters peculiar to the

cockroaches on the one hand and to the true termites on the other. Its general habitus is cockroach-like, and it has distinctly 5-jointed tarsi and an anal lobe to the fore wing, cockroach characters which do not appear in other termites. At the same time, as Holmgren has shown, this insect is not so clearly related to the modern Blattidæ, or cockroaches, as it is to their ancestors, the Protoblattidæ, which became extinct in the Permian. We are therefore justified in regarding the termites as primitive social cockroaches, which probably came off from the ancestral blattoid stem in late Paleozoic or early Mesozoic times. Some light is also thrown on the significance of Mastotermes by a study of the fossil termites. Although we have no paleontological records of these insects before the Tertiary, von Rosen has been able to discover four extinct species of Mastotermes, three (*bournemouthensis, anglicus* and *batheri*) in the Eocene and Upper Oligocene of England and one (*croaticus*) in the Miocene of Croatia. This indicates that the genus, now confined to Northern Australia and reduced to a single species, once contained many species and was distributed throughout the continents of the Old and probably also of the New World. Other termite genera are abundantly represented in the Baltic Amber and in the Miocene formations of Colorado and Europe, and von Rosen has shown that they belong to the two lower families of the higher termites, the Protermitidæ and Mesotermitidæ, the highest family, the Metatermitidæ, which builds the extraordinary nests in the tropics at the present day, being absent from the early Tertiary formations. This does not mean that the Metatermitidæ did not exist at that time but that the European climate during the Oligocene and Miocene may have been too cool for them. Even to-day they are almost exclusively confined to the warmest portions of the earth. In all probability, therefore, the termites, like the ants, reached their complete structural and social development in the late Cretaceous or early Tertiary and have since undergone very little modification.

It is difficult for the inhabitants of temperate regions to appreciate the great importance of the termites in the tropics where they may, at least locally, equal or even surpass the ants in the number of their colonies and individuals. Even the casual visitor to the tropics will be impressed by the abundance of ants, but he may never see the termites, because the wingless members of their colonies rarely expose their pale, thin-skinned bodies to the light and air, but keep them carefully concealed under the soil, in covered galleries or in the dead and rotting vegetation. He may be astonished to see the dark-colored, winged, sexual forms suddenly appear at certain times in great numbers, but unless he is an entomologist,

he will probably regard them as true ants. Closer observation, however, reveals the fact that the activities of the termites are both extremely helpful and extremely injurious to man. In South Africa Drummond long ago found that they perform an important function like that of the earthworms in moist temperate regions, but on a vaster scale. Since they are so very numerous and feed almost exclusively on dead vegetable substances they conspire with the bacteria, high temperature and humidity to accelerate the disintegration of all the lifeless plant matter and to convert it into humus which can be at once utilized by the growing vegetation. The termites are therefore important agents in assisting the growth and renewal of the great rain-forests of the Amazon, the Congo and the East Indies. But even in the dry savannahs of South America and Africa and the open forests of Australia they hasten the dissolution of the dead grasses and other herbaceous plants as well as that of the sparse bushes and trees. On the other hand their insatiable appetite for cellulose and anything containing it makes these insects a terrible menace to all wooden construc-

FIG. 94
Damage by *Calotermes hubbardi* to rafters in an "adobe" building in Arizona. (After Thos. E. Snyder.)

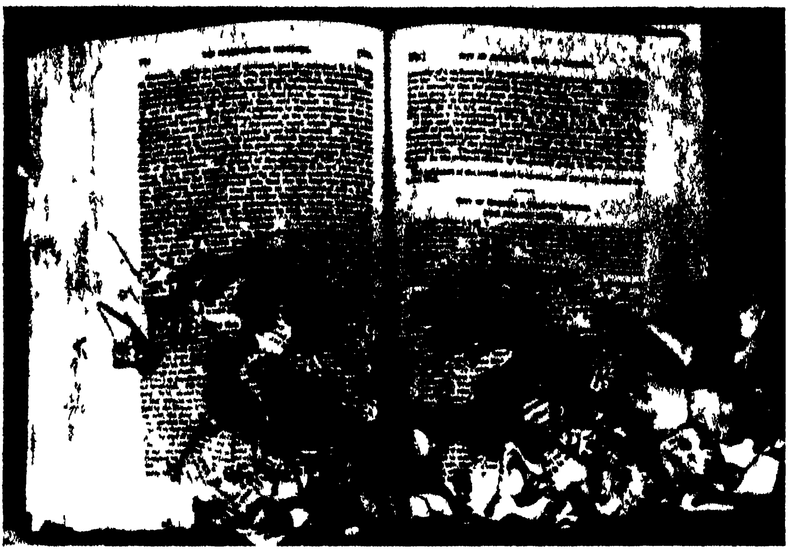

FIG. 95.
Book from the library at Van Buren, Arkansas, ruined by termites. (After Thos. J. Snyder.)

tions, such as fences, telegraph poles, houses, railway ties, bridges, furniture, ships, fabrics and books (Figs. 94 and 95). They do millions of dollars worth of damage annually. It has even been claimed that their fondness for literature is in part responsible for the slow cultural growth of many tropical countries. Alexander von Humboldt states that he rarely saw books more than 50 years old in Northern South America. The termites have undoubtedly obliterated so many of the records of human achievement that they must be regarded as the subtlest enemies of the historian and archeologist. The damage is so serious that progressive tropical communities are now beginning to use stone, cement and iron instead of wood in the construction or at least in the foundations of buildings.

Termite, like wasp, bee and ant colonies, show an increase in population as we pass from primitive species, such as the Protermitidæ, to such highly specialized form as the Metatermitidæ. Thus the colonies of Calotermes, Archotermopsis and Termopsis consist of only a few dozen or a few hundred individuals, whereas those of the higher termites may comprise hundreds of thousands. Andrews estimated the number of individuals in a moderately large colony of *Eutermes pilifrons* as 631,878. The populations of some African, Indian and Australian Metatermitidæ probably run into the millions.

The polymorphism or caste development is strikingly like that

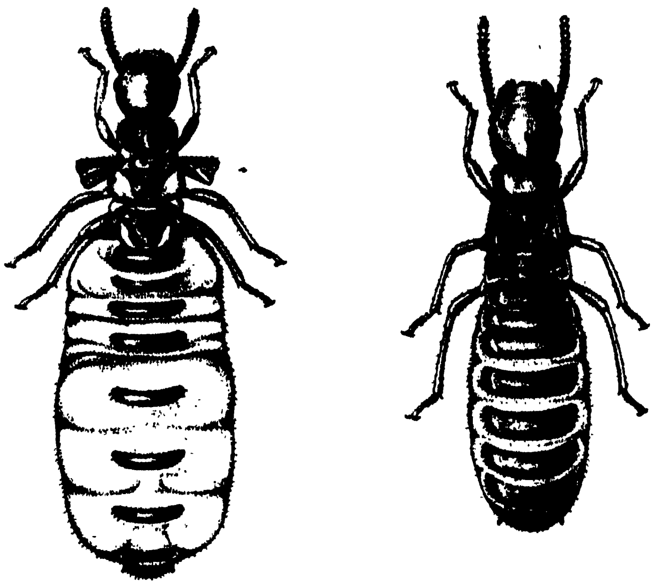

FIG. 96
Reticulitermes flavipes. *A.* Old, deälated, physogastric, first form queen. *B.* Old, deälated, first form king. (After N. Banks and T. E. Snyder.)

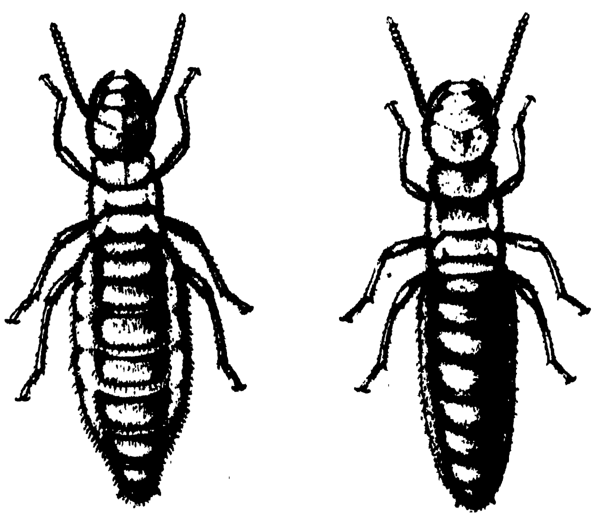

FIG. 97
Reticulitermes tibialis. *A.* Incipiently physogastric, apterous queen of the second form; *B.* Apterous king of the second form. (After N. Banks and T. E. Snyder.)

of the ants, but closer study shows that the resemblances really conceal remarkable and complicated differences. In ants we distinguished only three or four castes: males, queens, workers and soldiers, the last appearing only in certain species. Only one of the castes is male and is socially unimportant, while the three others are exclusively female. In the termites both sexes are of equal social importance, because each caste comprises individuals of both sexes, though they are almost or quite indistinguishable externally. In the great majority of species there are five castes, three of which are fertile and two sterile. They may be briefly characterized as follows:

1. *First form adults* (Fig. 96), usually called kings and queens. They are very similar, deeply pigmented insects, with large compound eyes, large brain and frontal gland, well-developed repro-

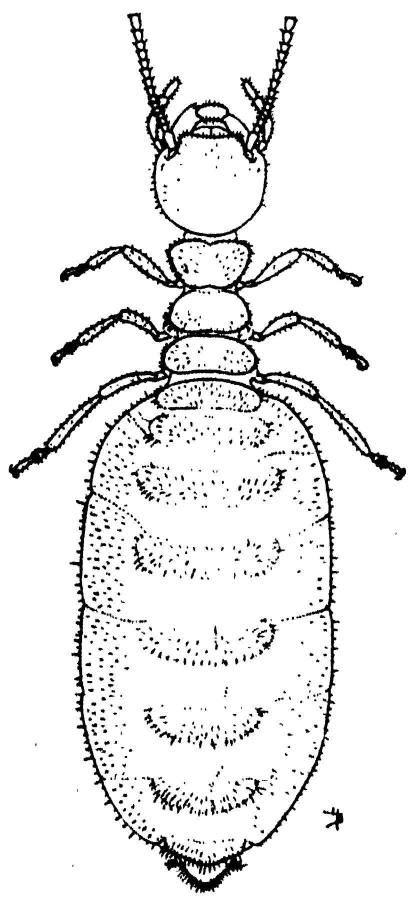

FIG. 98

Mature, apterous, third form queen of *Reticulitermes flavipes*. (After N. Banks and T. E. Snyder.)

ductive organs and at first with well-developed wings, but these later break off at preformed basal sutures and are discarded. Old individuals of this caste therefore can always be recognized by the truncated wing-stubs.

2. *Second form adults* (Fig. 97), sometimes called neoteinic, complemental, or substitutional kings and queens. Less pigmented, with wingpads, or incipient, nonfunctional wings; brain, compound eyes, frontal gland and reproductive organs somewhat smaller than in the first form.

3. *Third form adults* (Fig. 98), sometimes called ergatoid complemental or substitutional kings and queens. Scarcely pigmented; entirely wingless. Brain small; eyes and frontal gland vestigial; mature reproductive organs smaller than in the second form.

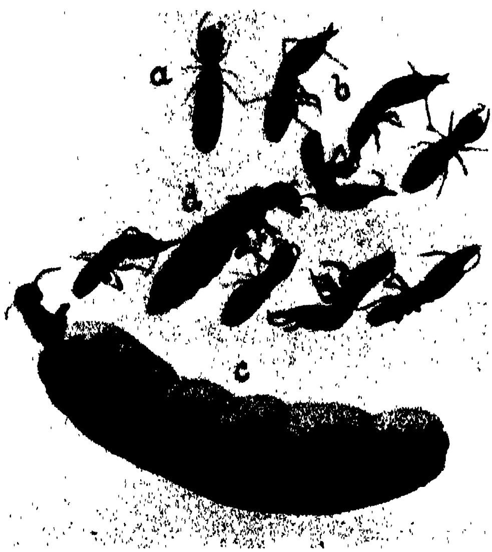

FIG. 99
Leucotermes tenuis of the Bahamas. X2. *a*, worker; *b*, soldier; *c*, physogastric queen; *d*, king.

4. *Workers* (Fig. 99*a*). Wingless, unpigmented; brain small, compound eyes and frontal gland extremely small or absent; reproductive organs embryonic, non-functional. Head broader than in the first and second adult forms.

5. *Soldiers* (Fig. 99*b*, Fig. 103). Wingless; head large and more or less pigmented; brain very small; compound eyes vestigial; head, frontal gland and in many species the mandibles and

mandibular muscles large (mandibulate) soldiers. In a few genera the soldier caste is represented by a different form, usually smaller than the worker, with retort-shaped head, produced anteriorly in the form of a long, tubular snout, with the opening of a large frontal gland at its tip. This form is known as a "nasutus."

The following deviations from this typical series of castes may be noticed. In some Protermitidæ (Calotermes, Archotermopsis, Termopsis) the worker caste is absent and its place is taken by the young soldiers and sexual forms. In another genus, Anoplotermes, the soldier caste is absent though typical workers are present. In some genera (Eutermes, Rhinotermes, Acanthotermes, Capritermes, Termes) there are two or even three different types of soldiers, and in a few genera (Synacanthotermes, Termes) there are two different types of workers. Hence we have the following eight castes, each represented by males and females and therefore making 16 different kinds of individuals:

1. First form males and females (true kings and queens).
2. Second form males and females.
3. Third form males and females.
4. Large male and female workers.
5. Small male and female workers.
6. Large male and female soldiers.
7. Medium-sized male and female soldiers.
8. Small male and female soldiers.

Probably no single colony of termites ever produces all of these castes, but five or even six of them are frequently represented. Attention should be called to the fact that the soldiers and workers are really larval (nymphal) forms that have been arrested in their development and peculiarly differentiated in certain characters. The second and third adult forms are also arrested, at least so far as the development of their wings is concerned. Owing to the fact that their bodies are still immature or larval, though their reproductive organs may be functional, they have been regarded as "neoteinic."

Although the origin and meaning of the various castes in termites is a matter of considerable interest and has given rise to much discussion, I shall have to treat it very briefly. It was formerly supposed that all termite eggs were alike and therefore produced young larvæ which were at first the same but took on the various caste characters as a result of differences in feeding (trophogeny). Recently, however, Bugnion and especially the late Miss Caroline Thompson of Wellesley have shown that the castes are at least to an important degree determined in the egg. Miss

Thompson found that the very young nymphs or larvæ on hatching may be divided into two series, one with larger, the other with smaller brain, eyes and reproductive organs, and that the former give rise to the reproductive, the latter to the soldier and worker castes (Fig. 100). In all probability even closer study will show that each of the three reproductive and each of the two sterile castes may be distinguished at the time of hatching by certain slight internal characters. The observations of Miss Thompson and Snyder also indicate that each of the adult sexual forms can reproduce itself and the forms below it in rank, but not those above it. Thus the first form adults or true royalty can reproduce all the castes, the second form adults can reproduce their own form, the third form, the soldiers and workers, and the third form adults can reproduce only themselves, the soldiers and workers. The soldiers and workers are normally sterile, but sometimes they become fertile and on such occasions probably reproduce only their

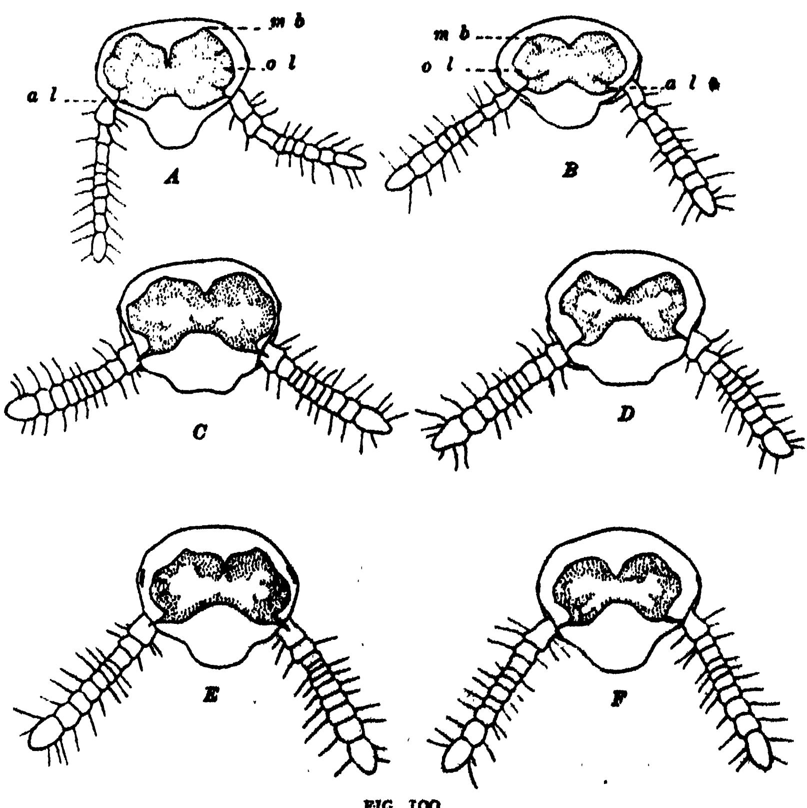

FIG. 100

Sections of heads of young termites to show relative size of brain and eyes. *A, C* and *E*, just hatched reproductive forms; *B, D, F*, just hatched worker-soldier forms. *mb*, mushroom body of brain; *ol*, optic lobes; *al*, antennary lobes. (After Caroline B. Thompson.)

own castes. It would seem, therefore, that the various castes, except the first, are really mutations, partly fertile and partly sterile, and comparable with the series of mutations which certain plants tend to produce in each generation (*Oenothera Lamarckiana*). This brings us back to Darwin's discussion of neuter and sterile insects in the eighth chapter of the "Origin of Species," where, referring to the garden stock which produces single and double flowers, he says: "According to M. Verlot, some varieties of the double annual stock from having been long and carefully selected to the right degree, always produce a large proportion of seedlings bearing double and quite sterile flowers; but they likewise yield some single and fertile plants. These latter, by which alone the variety can be propagated, may be compared with the fertile male and female ants, and the double sterile plants with the neuters of the same community. As with the varieties of the stock, so with social insects, selection has been applied to the family, and not to the individual, for the sake of gaining a serviceable end." If further investigation, as now seems likely, extends Miss Thompson's interpretation and shows that each termite hatches from the egg as a recognizable member of a particular caste, we shall have to revise our views on caste differentiation in the ants, because the same explanation may apply to them. It is, in fact, not improbable that the caste of a particular ant is likewise determined in the egg, but special feeding of the larva may be necessary to bring it to maturity. The passively fed ant-larvæ are certainly very different from the active termite nymphs, which soon after hatching are able to run about and seek their own food.

The social functions of the various termite castes correspond to those of the analogous castes among ants. The dark-colored, winged kings and queens, soon after reaching maturity, suddenly leave the nest in a swarm and fly up into the air. This has been called a nuptial flight from analogy with the flight of the male and female ants, but as it is not accompanied by mating, it is more properly called a flight of dispersion. The kings and queens after spending a very short time in the air, alight on the ground, throw off their wings and associate in couples, the king running along after the queen. As soon as they find a convenient spot each couple digs a small chamber (Fig. 101). Both insects work together on its excavation, and it is not till their habitation is completed that mating occurs. The whole termite colony is the offspring of such a royal pair, just as the ant-colony arises from the single fecundated queen. In the lower termites the queen undergoes little change in shape since she produces few eggs and those at rather long intervals, but among the Meso- and Metatermitidæ, which keep their

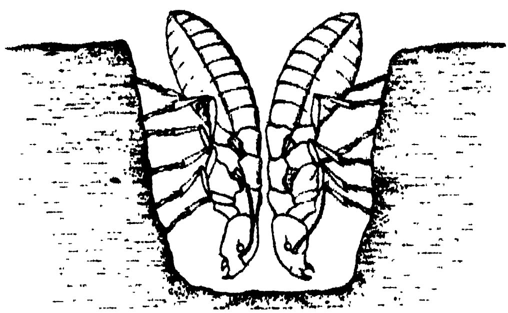

FIG. 101
Young king and queen of *Hodotermes turkestanicus* beginning to dig their burrow in the soil after the dispersion flight. (After G. Jacobson.)

king and queen in a special royal chamber in the middle of the termitarium, the queen's abdomen swells to extraordinary dimensions as a result of the amount of food she is given and the enormous growth of her ovaries and fat-body (Fig. 99*c*, 102, 103). In some species of Termes she may attain a length of four inches and 20,000 times the volume of one of her workers. Escherich,

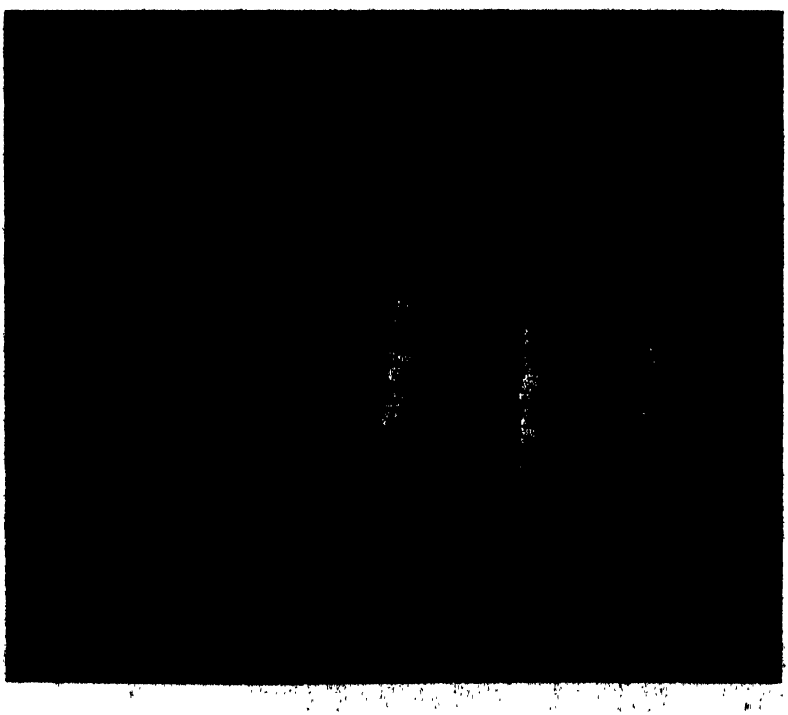

FIG. 102
Three physogastric queens of *Termes*, sp. in the same royal chamber. (From a photograph taken by H. O. Lang at Niangara in the Belgian Congo.)

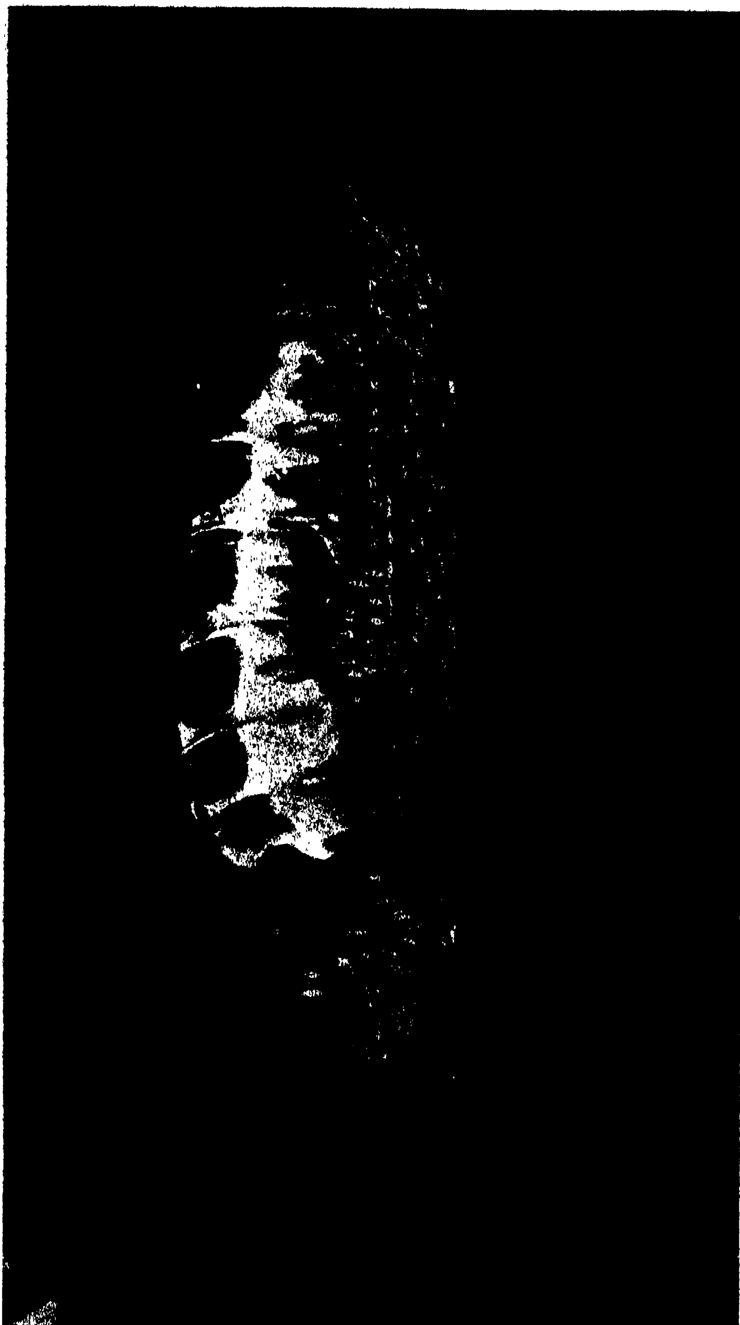

FIG. 103

Scene in the royal chamber of the African *Termes bellicosus* showing the king, physogastric queen and the attendant soldiers and workers. (From a water-color drawing by G. Kunze. After Prof. Karl Escherich.)

who has studied the fertile queens of various Abyssinian and Indian species of Termes, gives a remarkable description of their machine-like—he calls it factory-like—oviposition. Since one of these queens lays an egg every few seconds with clock-like regularity, he estimates that she must lay about 30,000 a day, 10 million a year and 100 million during her lifetime of about ten years. Certainly the Termes queen outrivals in fecundity any other terrestrial animal.

The second and third form adults are usually interpreted as substitute royalty, *i. e.*, as forms which may take the places of the true king and queen if they happen to die. Fritz Mueller found in the nest of a South American Eutermes a true king with a harem of 31 queens of the second form, and Holmgren describes another South American termite, *Armitermes neotenicus*, in the colonies of which he constantly found a true king with a harem of about 100 females of the second form. The Swedish investigator believes that in this species true queens are no longer produced.

The function of the worker termite is, like that of the worker ant, mainly concerned with feeding and cleaning the other castes and constructing and repairing the nest. The soldiers of the mandibulate type are evidently defense organisms which use their powerful jaws like the soldiers of ants, but the nasuti, which are usually smaller than the workers and have vestigial mandibles, resort to a different method of fighting. Andrews, who studied the behavior of *Eutermes pilifrons* in Jamaica, says that the nasuti "are potent defenders of the community, at least against other communities. Nasuti were seen to attack alien nasuti and workers by thrusting their snouts against and close to the enemy and ejecting a minute amount of liquid from the tips. This liquid is perfectly clear and colorless. . . . When a coverglass was held over excited soldiers this secretion was collected as if by squirting across space. When drops of it were injected by the soldier onto the heads of other soldiers and workers it seemed to produce a sort of paralysis, which in some cases was connected with the adhesion of the antennæ to the head. . . . The secretion seems to act merely mechanically to stick legs, etc., till the foe was powerless."

The feeding habits are very complicated. Although dead wood and other dead vegetable substances are gnawed off and ingested by the individual termites, they have also developed a very elaborate system of mutual feeding (trophallaxis). They feed one another with saliva, with regurgitated, partially digested food (so-called stomodæal food) and with food that has passed through the alimentary canal, *i.e.*, with feces (proctodæal food). But even this

does not exhaust the nutritive resources of these extraordinary insects. Holmgren finds that all the castes produce exudates, that is, fatty substances which, arising from the fat-body and blood-plasma, exude through the thin chitinous investment of the abdomen onto its surface and are licked up by other members of the colony. There seem to be as many different kinds of exudates as there are castes, and probably the castes are recognized by their taste. The physogastric queen produces the most delicious and the most copious exudate and is therefore constantly surrounded and licked by a host of workers (Fig. 103). According to Escherich, her exudate is so attractive that the workers in order to make it flow more abundantly will even tear little strips out of the royal hide. He also states that many old queens bear the scars of such treatment as small brown spots or freckles on their milkwhite bodies. We have seen abundant evidence of trophallaxis among the ants and social wasps, but in none of them is it so elaborately developed as in the termite colonies, the members of which may be said to be bound together by a circulating medium of glandular secretions, fatty exudates and partly and wholly digested food, just as the cells of the body of a higher animal are bound together as a syntrophic whole by means of the circulating blood.

(To be concluded)

FIESTA AT SANT'ANA, NEW MEXICO

By ELSIE CLEWS PARSONS

IN Keresan towns saint's day dances are almost the only dances open to whites, and they attract visitors, all told, in large numbers. And yet aside from a slight account by Lummis of the dance on July 14 at Cochiti I know of no description of these dances at all adequate for either tourist or anthropologist, for both of whom they are full of interest. They are a very vivid expression of historic continuity or, if you prefer, of what sets up when two different cultures come into contact, two cultures or rather three—Pueblo Indian, Spanish, "American."

The pueblo of Sant' Ana is a mission of the Franciscans at Jemez, several miles north, up the Jemez river. The padre had not only to hold mass on the morning of his visit to Sant' Ana; there was a baby to baptize and two graves to bless. As the padre walked into town, leaving the buggy in which one of the devout had brought him across the wash and the drought-dried river bed, the church bell was sounded—knocked with a stone, a substitute for a missing clapper. Several young women who were graduates of the Sisters' schools in Santa Fé or Bernalillo greeted the padre cordially in English. Outside the sacristy the padre was greeted also by the four Sisters who had come up from Bernalillo to sing, and, in Spanish, by the *sacristan* of Sant' Ana and the *fiskales*, church officers of Spanish days.

Burials are still made in Sant' Ana in the churchyard,[1] the graves unmarked by mound or cross. The church faces south, so the grave is orientated north and south.[2] As the padre read the service, while several men stood in a half circle at the foot of the grave, a woman and child[3] joined them. From their heads the men removed their *banda*.

Into the baptistry a baby was carried by its *madriña*, and the very elaborate baptismal ritual of the church was performed. I had not realized how likely to impress a ritualistic people this

[1] In attempting to establish a cemetery elsewhere or even to enlarge the churchyard the Church meets with grave opposition.

[2] In several pueblos—Zuñi, Acoma, Isleta, Taos—people will not sleep orientated as in burial. Among the Hopi where there is no churchyard burial there is no aversion to sleeping in any position. Orientation in burial and in sleep has been of Spanish provenience.

[3] In the west, *i. e.*, at Zuñi and among the Hopi, women and children do not attend a burial.

Catholic ritual must ever have been, with its applications of oil and of water to the various parts of head and body, *its rite of breathing upon the infant*,[4] the numerous prayers with frequent change of vestments and use of lighted candles. In holding the candles and in responses to the prayers a *fiskale* assisted. There was no *padriño*. The child had been born some time before St. John's day; for the time being a closer reckoning was not possible, and there was no father of record. "For my grandchild," said an older man in offering his coin to the padre.

The water was poured on the head of the infant from a metal container in the shape of a shell—medicine-water is commonly administered in Pueblo ceremonial from a shell and in the baptistry stood a portable wooden niche for a saint's image which in construction and coloring was extremely suggestive of the altar frames of Zuñi societies.[5] The lower parts of the panels were painted white, the upper part green-blue or yellow, with diagonals between the parts of the white and black block pattern, used so much not only on Pueblo altar frames but on the kachina masks. On top of the niche was a design of a sun in red banded with semi-circular lines of yellow, blue, red and white, the usual color circuit association.

The image of Sant' Ana rested on a table in the middle of the church. Under the table was a large and handsomely decorated pottery water jar, and propped against the table were three of the "officers' canes."[6] Many candles stood on the ground in front,

4 Expiration figures in native curing ritual, and head washing in native initiations and other ritual.

5 The esoteric organizations for curing or weather-control to which a large number of the townspeople belong.

6 The "officers in a Keresan pueblo are the governor and his lieutenant, three "war-captains," and a varying number of *fiskales*. They are appointed annually, by the native hierarchy which is the real government of the town. The "officers" are a Spanish institution which has served the hierarchy as a go-between with the whites.

A Spanish or Mexican town official is possessed of a stick or cane of office *(vara)*, and the Pueblo "officer" came into one. President Lincoln, tipped off by some one who was unusually well informed, presented all the Pueblo governors with silver headed inscribed canes, a rarely intelligent gift.

Like the *vara* (or the sceptre) these canes have a fetichistic character. They are still blessed, *i. e.*, aspersed in some of the churches on Kings' Day (January 6) and in one town they are even sprinkled with prayer meal.

Pueblo societies and persons holding ceremonial office may also be possessed of sticks of office. At Laguna I have heard of the "war captains" placing their canes on native altars. "They are a protection," just as no doubt these Sant' Ana canes (probably the *fiskales'*) were thought of as a protection to the saint. Her improvised altar, canes, water jar, and manner of placing the candles were all together not a little suggestive of native altars. Better had the saint been placed on the ground, but the table was the Spanish of it.

and these were added to by several worshippers who, before placing down their candle and lighting it, would touch the saint near her heart or on the beads around her neck. One old man, arrayed in a Mexican poncho of blue cloth, a type of shirt rarely seen to-day, and shaps of yellow kid or buckskin, having placed his candle in the most conspicuous position in front of the saint, knelt on both knees behind it during the entire service. Afterwards he walked in the procession on the right hand of the padre. Probably he had taken a vow. Not long since at Jemez, the padre told me, the father of a little boy, lost in the mesas, had vowed that if the child were recovered, he would serve as *padriño* to the *santu hijo* (godfather to Jesus) during the following Christmas, fulfilment of which meant giving costly entertainment to many visitors. From motives comparable, entertainment is given to the kachina at Zuñi by the entertainers of the *shalako,* bestowers of beloved offspring.

To return to church at Sant' Ana—on the floor opposite the becandled saint were placed many baskets of produce, twenty or more, mostly wheat in the grain, some with rolls of bread on top, and in one basket were piled ears of dark blue or black corn.[7] Here, too, were lighted candles; in their flicker the richly colored offerings made a very pleasing show. Above it, painted on the white wall of the church, were two great tasseled stalks of corn and two more on the church wall opposite, all four designs rising out of the stripe in color of red soil running around the base of the walls. Do not the saints as well as the kachina bring crops, since they bring rain? It had always rained, I was told, the afternoon of the fiesta of Sant' Ana.

On the wall near the church portal hung what at Cochiti used to be called "God's whip," a wooden handle with holes at either end, for loop to hang by and for the knotted hide thong. The whip hangs on the wall, but it is no longer used at Sant' Ana, where formerly, as at Cochiti, it figured in the summons of delinquents to mass by *fiskales.* Were the jucca switches of the kachina suggested by "God's whip" or, perhaps, by the jucca lashes of the Penitentes?

At the close of mass the drum outside the church was beaten and guns were fired off. The procession started: first, the saint carried by four girls, her cotton panoply attached to four poles, supported by four men, then a crowd of worshippers, then the padre, habited now in his brown Franciscan cowl with corded belt and in sandalled feet, on his right the solemn old man dressed in his Spanish heirlooms, behind them the four black habited Fran-

[7] This is the colored corn which is given as tithes, so to speak, to the Town chief, the so-called cacique or head of the hierarchy.

ciscan Sisters, and straggling last, three or four "Americans," one, God forgive him, with a camera.

The Franciscan Sisters led the singing, processionals now in Spanish, now in English. The circuit was characteristically anti-sunwise, from church door in the east northward, westward, southward, then down the plaza, the Middle as the townspeople say, to the bower of spruce, the saint's house, at the north end. At the cardinal points in the route cottonwood branches had been planted, and at each point for a few moment the procession halted.

The saint is placed in her house of green, her followers disperse, in the plaza appear six *koshare* to dance in line abreast up and down the Middle. Their bodies are bent forward as they caper with arms now and again outstretched. Posture and gestures are like those of the *koyemshi* of Zuñi or the Hopi *wöwöchimtu* or the Jemez *tabösh* or the Black Eyes of Taos, and their singing likewise reminds one of those other clownish groups, buffoons and burlesquers and potent withal in the hierarchy.

Two of the *koshare* wear grey skull caps, streaked in black, the others have their long hair parted and tied up on either side with a bunch of corn husks. Face and body are painted grey, with black stripes, three black rings around arms, body and legs, and eyes and mouth black encircled. They wear dilapidated moccasins and a ragged loin cloth or apron to which sheep toes are attached as rattles. Under both knees is tied black yarn. In both hands spruce twigs are carried. Around the neck is a string of yellow berries, the Jerusalem cherry.

After this dance it is dinner time, and there is going and coming from house to house and around the two booths some Mexicans have installed to sell sweet drinks, candy, etc. On a house ruin near me stands a group of young men to whom another Mexican is trying to sell some Navaho silver ornaments. "Mal fiesta, mal fiesta," he grumbles as not a boy takes interest in his ware. . . . The dancers are assembling in the two estufas,[8] and from one to the other old men pass, carrying dance paraphernalia, and the *koshare* who *go down the ladder head foremost.*[9]

[8] The estufa (Spanish) or kiva (Hopi) is a kind of club house, where dances or ceremonies may be held, and which is used more or less as a lounge or workshop by the men. All Keresan towns, except Acoma, have or had a double estufa system, the two estufas commonly called Squash and Turquoise. Children, boys and girls, go to the estufa of their father, a woman, after marriage, to that of her husband. The societies have their own separate meeting places, but the dancer kachina groups and the clown societies make use of the estufas.

[9] As do at times some of the Zuñi masked dancers or kachina, in imitation, they say at Zuñi, of the woodpecker, a bird associated with the war cult, and these are warrior kachina.—Many war traits attach to the phallic clown societies whose historical connection with the military societies of the Plains Indians may some day, I think, become clear.

From the hatchway of each estufa projects the standard that is to be carried in the dance. The head of the standard is a gourd painted green with an encircling block pattern of white and black. Above and below are fringes of red horse hair, on the very top a bunch of parrot feathers, and over them hawk or eagle feathers. Below the gourd is a kilt of native cloth, and a long strip of native cloth to which eagle feathers are fastened extends half way down the pole. It is a gay and stylish standard used in all Keresan church fiestas, and a like standard is carried by the Sun society of Jemez, which sings for the women's harvest dance. That the standard was raised from estufa hatchway while preparations were going on within is quite analogous to the placing of a standard in the hatchway in Hopi ritual.

Some drums are also to be seen on the estufa roofs—painted carmine on the southwest estufa towards the river, Squash estufa, and violet blue on the estufa on the northeast side of town, Turquoise estufa. . . . The Turquoise estufa dancers are out first, to dance up to a position in front of the church. Ahead is carried the standard with the dancers behind, two men, two women and so alternating, couple by couple.

The men wear Hopi dance kilt with Hopi belt of heavy knot and long fringe and at the back the pendent foxskin. Bells are tied with yarn under both knees, spruce twigs encircle the belt, and spruce is carried in the left hand, in the right, a carmine gourd rattle. They wear olivella shell necklaces and over their moccasins skunk-skin heel bands. Legs, arms and hands and upper body are painted a violet blue (a commercial dye, alack, which is being used, I am told, for the first time) and down the back are in darker tint four zigzags. The hair of some of the younger men and boys is short (another unhappy Americanism), of the older men, flowing, in the hair of all on top is a bunch of parrot feathers.

The women dancers wear their native cloth dress, the ugly calico slip happily tucked away, leaving arms and left shoulder bare. They are barefoot, in each hand spruce twigs, on each cheek a round of red paint.[10] Their hair is flowing, surmounted by a *tablita* of turquoise painted wood cut on top in the double cloud terrace design, at each of the four corners two turkey feathers, the feathers ever associated with the dead and with rain-makers.

There are several dance figures, a song to each figure, with a short pause between. In one there are two rows of women in the middle, the rows of men on the outside; another figure is down the middle and back like a reel; in another, two rows, men and

10 That this fashion, not uncommon in the get up of women dancers, is of Mexican provenience Lieutenant Simpson gives testimony. "Not unfrequently they [Mexican women in New Mexico] are covered with a red pigment in blotches," giving "to the face a frightful and disgusting appearance." *Reports of the Sec. of War*, p. 133, *Ex. Doc.* No. 64, 1850.

women alternating, face each other and then in groups of four or six break up to dance in a circle and return to place. The choir dances up and down in irregular lines, before the church on the right of the head of the dancing lines, in the plaza, on the left. The singers carry spruce in their hands which are painted the same violet-blue. A piece of spruce is stuck behind in the belt of the drummer. Spruce is indispensable to the saints' dancers as well as to the kachina.

The dancing before the church concludes, and as the dancers walk away in single file they pass close to the other dance set coming in from Squash estufa. The Squash estufa dancers and choir resemble the other estufa set in all particulars but the color of their paint, which is carmine. In both dance sets there are from forty to fifty dancers, with about fifteen singers in each choir.

We leave the Squash estufa people dancing before the church and follow the Turquoise estufa people in to the plaza. Down the Middle they dance until they take position before the saint's bower and repeat all their dance figures, which takes about forty minutes. At one time the standard bearer leaves the choir to manipulate his standard with a quivering motion over the head of the mid-line dancer, the dance leader. . . . After this first dance before the saint every dancer enters her house to say a prayer and *to breathe from her*, a native breath rite. Several dancers place food offerings by her table, one girl drapes over the saint's shoulders a silk kerchief, an indispensable part of gala dress and a gift highly acceptable to any Pueblo woman.[11]

Again as the Turquoise estufa group walks out, the Squash estufa group comes in, dancing. From now on alternation in the plaza by the two groups will continue until sundown; but the padre is desirous of being monastery bound, after all, his part is over, and so we leave town. Again in his honor the bell is aclang, its sounds mingling with the far carrying notes of the choir, singing repetitiously,

hama kaach, hama kaach!
Long ago it rained, long ago it rained,

words quite appropriate, as it happens, to that long season of drought, which, despite the boast of customary rainfall, neither the dance we have just seen is to break nor yet the dance a few days later in honor of another saint, Porcingula, once of Assisi, then of Pecos, now of Jemez. The first rain of the season falls the day after the Water Serpent is brought from his spring into Jemez to the altar of the Flint Society.

[11] Taos women excepted, since they alone of Pueblo women do not wear the kerchief across the shoulders, without which, if she went outdoors, says the Zuñi woman, she would feel naked and ashamed.

THE SOCIAL-SIGNIFICANCE OF THE ARMY INTELLIGENCE FINDINGS

By Professor PERCY E. DAVIDSON
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THE spectacular significance of the army intelligence data is found in their damaging consequences for certain pivotal articles of faith in the American social-political tradition. Because they demonstrate, at best, an adolescent mentality for the masses of the people, the traditional democratic aspiration for a social order resting upon an enlightened and cultivated general will must be renounced. Obviously a relatively childish mentality can not support institutions presupposing rationality and refinement. By implication society must be governed, however circumspectly, by the gifted minority. Because they have shown that class and income levels reflect a natural biological stratification, modern democratic movements looking towards the leveling of inequalities in income, social prestige and social power are doomed to futility and but serve to incite the less well-to-do to irrational discontent and reckless revolt. Because of the limitations of natural endowment on the part of the multitude, elaborate and costly programs for universal education are illusory and wasteful, and should be circumscribed in the interests of the more able. If the army intelligence findings justly support these serious strictures upon currently accepted notions, certainly their importance has not been exaggerated.

They do so only when three assumptions are first regarded as securely established: one to the effect that the army draft was truly representative of the American population at large; the second predicating that the tests employed were tests of native intellect rather than of cultural achievement; the third implying that the native intellect in question is so general in its nature as to condition social success or social achievement of any significant kind.

As to the representative character of the army draft there have been differences of opinion, since accurate knowledge is not at hand. It is noted in the official report[1] that the effect of defer-

[1] "Psychological Examining in the Army," Memoirs of The National Academy of Sciences, Vol. XV.

ments and exemptions was such as to make "the tendency of the selective service act to send men to camp who on the average are probably slightly inferior to the average of the general population." A reading of the list of occupations reported will show that the army draft was not thoroughly representative of American industrial society. The distinctly greater number of the designations refer to artisan trades; there is a considerable number of clerical occupations and a scattering of the semi-professional. The great farm-holding group seems not to have been represented by the category "farmers," apparently made up chiefly of unmarried farm hands. The independent business community was similarly not represented. Such members of these groups as entered the service presumably became officers of one sort or another or joined the subsidiary relief and welfare organizations. These groups contain something like 30 per cent. of the working population and quite possibly have in them a disproportionate share of abler individuals. It will thus be seen why the scores of the draft are not regarded as picturing faithfully the intelligence of the general population, and why the reservations of the official report may very considerably understate the amount of the discrepancy. The presumption is, consequently, that generalizations from the selected groups do not accurately carry over to the general public, and so fail to do justice to its intelligence.

But a much more hazardous assumption is that which assigns to the army tests the power of reaching beyond the effects of training and of measuring native intellect. It is now a commonplace in the discussion that innate differences are known only when opportunities for practice have been equalized. This is to say that a test or examination *per se* can never be regarded as a test of native capacity. It is such only under highly favorable circumstances, these obtaining—if they ever do—when the physical and social environments have from birth made equal demands upon those who take the tests. The conceivable subtlety and delicacy of these demands and the consequent differential effects in accumulated habit might well be stressed here in connection with the whole problem of mental testing, but the applications for the army results are primarily in question. Some relevant data may be briefly reviewed.

The Alpha examination contains tests that bear heavily upon familiarity with language, knowledge of number and general information—all matters that may be thought of as strongly affected by unlike conditions on the several social levels. When the distributions for each of the component exercises of Alpha are examined, it appears that only two of these approximate the normal curve and

these two not closely. For all of them the frequencies pile up on the lower scores, and it is noteworthy that the most frequent score in six of the eight tests is zero, a frequency that outnumbers the next largest several times in some tests. This means that an important fraction of the draft was unprepared to make one point on these tests, which leads the compilers to the natural inference that many of the poorer scores were made by persons handicapped by experience rather than by stupidity. The distribution of the Beta component tests are likewise suggestive of factors other than native talent. The language handicap in this test for foreign-born illiterates as compared with English-speaking illiterates has been definitely noted.[2] As for the negroes, so many of whom were examined by Beta, the consensus of opinion among the examiners was that this examination was not well adapted to their type of mind. Of a representative group of 1,216 men who failed in both group examinations and were recalled for individual testing, 49 per cent. of whites and 75 per cent. of negroes could neither read nor write; 39 per cent. of the whites and 59 per cent. of the negroes had not reached the first grade of school. More than half were "farmers," presumably from outlying and backward communities. The number free from disease was small. Nevertheless, 45 per cent. of whites and 44.6 per cent. of the negroes were placed in regular service and a median weekly wage of about $15 was reported for the whites.[3] Now if such were the circumstances of those failing to pass the group examinations, it is very probable that those making the lower passing scores were seriously handicapped in the matter of social experience and that their native ability was not fairly exhibited. To make the limitations of language and schooling wholly a consequence of an imputed stupidity flies in the face of all the probabilities, for we know as a matter of fact that persistence in school reflects not ability alone but family tradition, incentive to mental improvement, economic status and cultural opportunity as well.

That the scores in these examinations are materially affected by social experience is attested by certain other lines of evidence. An appreciable rise in them was found to accompany length of residence in this country on the part of the foreign-born, amounting to two years of mental age when the first five-year interval is compared with the fourth. There seems little reason to suppose that the first-comers were more able than their successors. With respect to the nativity of the foreign-born, "the range of difference

2 Myers, *Journ. of Educ. Psych.*, April, 1921.
3 "Memoirs," Part 3, Chap. II, Sect. 2.

is a very high one. Among the men from England only 8.7 per cent. were rated D or less, while among the Poles the percentage making these low ratings was almost 70. In general, the Scandinavian and English-speaking countries stand high in the list, while the Slavic and Latin countries stand low" (p. 699). The disparity here is so great in amount as to suggest other than selective factors at work. The great differences are shown between languages most removed in kinship, which coincide with the most marked differences in the extension of popular education and popular culture. It is to be noted, furthermore, that the ratings of the negroes as a group are astonishingly low as compared with other obtained indices, and that the northern negroes are superior to the southern. Correlation of schooling with "intelligence" for the draft as a whole seems to have been as high as .75. In none of these data is it necessary to deny the presence of native differences. They are, however, such as to encourage caution in accepting the results as anything like precise measures of native capacity.

Studies of the influence of practice in the Alpha examination are of interest in this connection. College seniors who were given four forms of Alpha at intervals of three weeks showed striking improvement in the second and third trials. The practice effect for the lower half of the group was much greater than for the higher, indicating that the lower scores were in greater degree affected by the novelty of the tasks.[4] Similar results were obtained from retests in army groups with Examination *a*, which is of the same general nature as Alpha. One notes with interest that in a group of 190 enlisted men the letter-grade remained the same on the second trial with only 56 per cent. of the cases. The suggestion of inequality of practice antecedent to the taking of the tests in these observations is of first importance in the comparison of social classes. The natural inference is that the obtained scores from one trial, as well as the averages based upon them for occupational levels, are uncertain indications of what would hold in measures of capacity where equality of practice could be assumed. Sympathizers with those psychologists who contend that differences in the power *to learn, to acquire, or to improve by practice,* are the really substantial differences among individuals will hesitate to accept indices of native capacity derived from single performances where the antecedent practice is essentially unknown. It is just in this inequality of practice in all exercises highly subject to training that the experience of the several social levels is most unlike, with the obvious consequence that the lower or compara-

[4] Dunlap and Snyder, *Journ. of Exp. Psych.*, 1920, 3: 396.

tively unschooled classes suffer from an undue depression of their scores in such exercises.[5]

Significant facts bearing upon the influence of experience in the Alpha examination appear in a special study of some 2,500 medical officers believed to be representative of the profession.[6] In this study the average positions taken by officers of several different branches of service in the eight component exercises of the examination were compared and so-called psychographs for each branch were determined. A few incidental observations will illustrate the nature of the findings. In Test 8, dealing with rather indiscriminate items of general knowledge, for instance, it appears that the engineer officers and the chaplains fell upon the same percentile for all branches of service. But in Test 2 and Test 6, dealing with numbers, one finds the engineers holding a position twice as high as that of the chaplains. On Test 4, on the other hand, which relates to dissimilarities and similarities of words, the position of the chaplains is at the 80th percentile while the engineers' is found at the 62nd. Test 3 calls for the choice of the best answer to questions implying some scientific knowledge and inferences from it. Here the discrepancy is less and favors the engineers. Other tests perhaps call upon less specially trained functions. Probably no one will seriously contend that with the five of the eight tests referred to there was anything approaching equality of antecedent practice in the two vocations compared—native differences being left aside. One is therefore left in doubt as to the part played by native endowment in so small a group of tests, and the doubt carries over to the seventy occupations of the army draft. Did not the tests strongly favor, probably, the clerical occupations as compared with manual, and is the disparity in the averages for these two great groups of workers so large as the scores would indicate? And may we not fairly assume that there was in general a far greater proportionate amount of antecedent practice and habituation in all the upper level occupations in the exercises of these tests?

Significant for their bearing upon this matter of the incidence of culture upon the army Alpha scores are the following coefficients showing the measure of correlation found with forty-one American states as between the median scores for at least 500 draftees and the social-economic conditions indicated. Only white men are involved in the comparison.[7]

[5] On the reliability of single trials see Otis, *Journ. of Educ. Research*, 1921.

[6] Cobb and Yerkes, *Bulletin National Research Council*, Vol. I, Pt. 8, No. 8, 1921.

[7] Alexander, *School and Society*, September 30, 1922.

TABLE 1

Showing the coefficient of correlation for 41 American states in Army Alpha and

1. Per cent. of foreign-born	.65 ± .06
2. Per cent. of native-born of native parentage	—.61 ± .07
3. Per cent. of urban population	.62 ± .07
4. Per cent. of homes owned in rural states	.68 ± .07
5. Per cent. of farms owned in rural states	.66 ± .07
6. Wages for farm labor in rural states	.88 ± .03
7. Per cent. of literacy	.64 ± .06
8. Ayers' Index to State School Systems	.72 ± .05
9. Three, five, six, seven and eight (above) combined	.89 ± .02

While a sufficient faith in the existence of innate differences among American states may conceivably enable one to construe these coefficients without disadvantage to Army Alpha scores as measures of endowment for large social groups, it is probable that impartial minds will see in them confirmation of Davies' similar findings for production of persons of distinction. In fact a coefficient not reported in the above list for Army Alpha with one of Davies'[8] rank-orders involving 29 states, is .79 ± .05.

It thus becomes evident that the averages for the social groups studied by means of the army tests, whether of nationality or occupational level, must be conceived as recording in considerable part the differential effects of unlike social experience. For aught one knows to the contrary these averages may record such effects *only*, leaving intact an historical assumption, as plausible hypothesis at least, that the greater social groups in modern societies are essentially equally well endowed. At any rate it would seem necessary to go outside the army data for the decisive testimony.

Turning to the third assumption underlying the application of the army findings to the general population, we inquire as to the relation of the army-examination "intelligence" to those native abilities which "urge and enable one" to achieve in the activities of life at large. From the statistical nature of the occupational distributions Kelley infers "that factors other than general intelligence are very largely operative in determining selection of a vocation."[9] His coefficient for the test intelligence with these other factors is as high as .875. The study of the medical officers referred to above found no correlation of the test-intelligence with income from the practice of medicine. Whether it should or not, it is evident that society does not reward medical service in proportion to this type of intelligence. A high positive correlation was found in the army data with rank among enlisted men. Of the officers,

8 "Social Environment," 1917.

9 *Journ. of Applied Psych.*, Vol. I, 1917, p. 50.

it is stated, "On the whole it seems safe to say that among officers outside the Medical Department intelligence differences according to rank were, at the time and under the conditions of the testing, of no psychological significance" ("Memoir," p. 858). The obtained coefficients with academic grade among high school and college students range from .30 to .50 and average around .40, indicating that many other factors are at work in this preparatory type of social activity. Certainly the social significance of the army test-intelligence is not impressive on this meager showing, although their faithful devotees will doubtless contend that this is less a criticism of the tests than it is of the discrimination of the public.

The uncertainty which has been shown to envelop the three major assumptions upon which the use of the army data has been based for the characterization of the general population tends to minimize the importance of much of the current criticism of the democratic philosophy these data have inspired. A brief comment may be made upon those aspects of this philosophy touched upon in the opening paragraph.

Even if it should turn out from competent psychological investigation that average human endowment has been unduly magnified historically, it may still be asserted with all possible emphasis that no one knows what this average endowment is capable of achieving. What is known of its history from savagery to the existing measure of civilization speaks well for its future. The declaration that the average man can become a Darwin needs no refutation. But to deny him the capacity of appreciating civilization well enough to conserve and advance it through democratic methods, in behalf of a more harmonious and more admirable social order, is sheer dogmatism and not scientific inference from any evidence now at hand.

As to the biological stratification which is alleged to explain and justify existing class and income inequalities, very little can now be stated with certainty. A judicial review of the data relating to the class origin of persons of distinction does not sustain this view of the social structure. The economists have shown that existing income curves are absurdly at variance with the normal curve which would describe, presumably, the distribution of native ability. The much-quoted conclusions from the very few unrelated studies reporting the results of testing children of fathers on the several social levels require substantiation, both as to the competency of the tests, and as to the numbers and classifications of the subjects, to deserve a small part of the significance credited them in this connection. As a matter of fact the newer data from

the tests still leaves the discussion about where the probabilities of current theory put it. This is, in the mind of the writer, at a moderate degree of correlation between native ability and class position. The correlation is probably still less when income levels are in question. The reasoning is as follows:

If the upper social levels contain a larger share of native ability this must be due to the effect of one of two conditions, or of their combination. The one is the possibility that as each generation becomes adjusted to the social-economic system, it is sifted and sorted on the basis of its potential abilities, so that the more gifted persons tend to occupy the upper social levels, the less able to fall upon the intermediate levels, and the least able to settle towards the bottom. This process—designated as the "social ladder"—would favor a high correlation between native ability and social status. But there is also to be noted the supplemental effect of heredity in passing on to children some measure of the ability of the parents. If, therefore, the social ladder has operated with effect in earlier generations some part of the correspondence would be maintained. The coefficient of correlation between parent and child, as these have been ascertained from the studies of the biometricians, gather about .50 and fall in some cases to .30, which seems to mean that, as marriages go, any position above the average of the general population that a father may hold by virtue of his endowment, has already been reduced one-half in the son—on the average. The few ascertained grandparental coefficients are still lower, ranging from .15 to .30. The conclusion would be that in groups so large as social classes the effect of heredity in maintaining class differences in native ability must be confined to two generations following the original selection, and is really emphatic in one only. If there are forces at work tending to nullify more and more the effect of the social ladder, it would seem that any existing correspondence between ability and social status must tend to disappear. Such forces are at work in any country where the land and natural resources become increasingly inaccessible to the whole population by reason of their absorption into private holdings with the right of bequest, or wherever economic opportunity is withheld from ability either by direct favoritism or by a selective process of training based primarily upon family resources.

As for the situation at any given period in any country, it is evident that the correspondence of ability and economic level will depend upon the immediate history of that country. If conditions have been such as to provide wide opportunity for the operation of the social ladder within a generation or two, we should expect to find some such correspondence. In the United States a very

great industrial expansion has taken place within a period that involves no more than three generations. The frontier has been closed only within this period. At the same time a tremendous accession to the population has taken place, especially of immigrants of all degrees of ability presumably, who were thrust into a field of unexampled opportunity. It is almost inconceivable that a premium has not been placed upon ability in such circumstances. While the operation of the social ladder may be slowing down, as some students intimate, it does not appear likely that its earlier influence has as yet been spent, or that it can be completely nullified if the industry of the country continues to expand.

An important bit of evidence bearing upon the operation of the social ladder in this country, as it affects the large agricultural group, has been made available in a study of the careers of 2,112 present farm-owners in five mid-western states.[10] Of the whole number 25 per cent. received their farms by inheritance, 23 per cent. by purchase from a near relative. Thus 48 per cent. rose to farm ownership with the assistance of their families, freed in part from the competition which by hypothesis selects the more able for the higher economic levels. If it does not require extraordinary ability to acquire a farm by marriage this figure should be raised by 8 per cent., making 56 per cent. in all who were aided.

If it be assumed that this group is representative of the farmers of the country, and the further assumption be made that the aided 56 per cent. were sons, grandsons, or nephews of men who achieved farm ownership under pioneer conditions through their own exertions, it is possible to believe that the aided portion of the group inherited a measure of, but not an equal amount of, superior ability from their antecedents—if it in fact required exceptional ability to build up a farm under pioneer conditions. The 44 per cent. who attained to farm ownership without ostensible assistance may plausibly be credited with ability above the average, or at least above the average of farm hands. When all these assumptions are made the conclusion runs to the effect that farm-holding status is correlated with some measure of superior ability when the group is compared with farm laborers, and conceivably with economic groups of a higher status.

There is no knowing to what extent the situation in agriculture is typical of the industry of the country. But the picture suggested from this scant evidence is hardly one that would take form if the social ladder has been acting with drastic effect. The element

10 W. J. Spillman, "The Agricultural Ladder," *Proc. Amer. Econ. Assoc.* 1919, p. 170.

of economic assistance is too conspicuous and the force of heredity too uncertain to encourage belief in a close correspondence of ability and economic level. The probabilities seem to favor a moderate degree of correlation.

The amount of assumption and inference in this argument obviously deprives it of any special weight. It may perhaps have the merit of suggesting that the setting-up and perpetuation of biological superiorities and inferiorities along social-economic lines, so easily assumed in current accounts of the matter, is subject to conditions which require for their understanding elaborate sociological researches that have not as yet been made.

The implications for universal education are not obscure. Doubtless the gifted minority should be discovered, wherever it may happen to reside upon the social levels, and be given all possible encouragement. Traditional wholesale methods of schooling have been quite too negligent of this precious element in the population, and economic resourcelessness often hampers it. But it surely does not follow that the great majority should be denied any training by which it can possibly profit, because of an arbitrarily imputed stupidity. Scientific methods of training have not as yet been inaugurated either for the one group or the other. If the potentialities of average endowment are known only when they are thoroughly exploited, any neglect of them will be as wasteful from the viewpoint of the largest social good as would be the neglect of the highly endowed.

THE MATHEMATICAL SCIENCES IN THE LATIN COLONIES OF AMERICA

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THE early history of the mathematical sciences in America, especially in the Latin colonies, has received little attention at the hands of scientific men. It is the aim of this paper to pass in rapid review the early observations in astronomy, mathematics and physics made before 1800 in the French, Spanish and Portuguese possessions in America. By confining ourselves to the time since Columbus, we shall omit descriptions of the number-systems and calendars of the American aborigines; we mention here only the calendar of the Maya of Central America who had developed a wonderful number-system on the principle of local value, with a symbol for zero, about the beginning of the Christian era, or *several centuries before our Hindu-Arabic number-system was invented.*

1. *Astronomical determinations of geographical positions.* The period of geographical discovery with its long ocean-voyages demanded measurements to determine what place on the earth's surface the explorer had reached. Except for short expeditions, the daily records of speed and direction ("dead-reckoning") of a ship were inadequate. These data were supplemented by astronomical observations. The latitude of a place was much easier to determine than the longitude. An easy method consisted in measuring the angular altitude of the North Star above the horizon. An instrument, such as the astrolabe, which measured the angle between a line pointing directly to the North Star and a vertical line would suffice. In course of time various instruments of successively increasing degrees of precision came to be invented. Columbus used an astrolabe; so did many later navigators. The astrolabe was well adapted for finding roughly the meridian altitudes of the sun, but the latitudes computed from them with the aid of the early tables of the sun's declination were unreliable because of the inaccuracy of the tables. In 1867 an astrolabe was found on an old portage road at the Ottawa river in Canada which, most probably, belonged to Champlain and was lost by him in

1613.[1] On June 7, 1613, Champlain speaks of the difficulty of making a portage, which must have been at or near the place where the astrolabe was found. Before that date he records determinations of latitude regularly in degrees and minutes; after that date he gives only rough estimates in degrees. This fact was probably due to his loss of the astrolabe previously used in his measurements. The instrument found in 1867 was a circular brass ring 5⅝ inches in diameter, each quarter of which was divided into degrees, ranging from 0° to 90°. When held in suspension by a small ring attached to the edge, the 0° marks were at the top and bottom, and the 90° marks at the extremities of the horizontal diameter. A movable index, turning on the center, carried two sights. When the instrument was freely suspended by the small ring and the index was pointed to a star, the angle which the index made with the horizontal diameter gave the angular altitude of the star. This astrolabe weighs about three pounds and is kept as a precious relic of the time of French-American exploration.

A slight modification of the ordinary astrolabe was the nautical or astronomical ring; instead of the movable index it had a hole in the rim through which a ray of light from the celestial object passed and fell upon the inner graduated edge, thereby indicating the altitude of the object. Father Kino (whom we shall mention again later) in 1701 made determinations of latitude at the junction of the Gila and the Colorado rivers, near the present town of Yuma, by the use of an astronomical ring (anillo astronómico) as 35° 30′; in 1538 P. Nadal had estimated this latitude by the meridian altitude of the sun as 35° 0′. C. Delisle in his maps adopted the value of 34°. In 1774, Father Juan Diaz made it 32° 44′ and in 1775 P. Pedro Font,[2] 32° 47′. One of the early needs in exploration were maps. The determination of distances and relative positions called for measurements which before the advent of clocks and telescopes were necessarily very crude. The French geodesist, La Condamine,[3] in 1745 refers to a map of the region of Quito, engraved in 1707 by the German Jesuit missionary, Samuel Fritz. Condamine says: "Father Fritz, without clock and without telescope was not able to determine the longitude of any point. He had only a small half-circle of wood, three inches in diameter,

[1] O. H. Marshall: "Champlain's Astrolabe" in *Magazine of American History*, Vol. III, p. 179. See also A. J. Russell *On Champlain's Astrolabe*, Montreal, 1879; Slafter's edition of *Champlain's Voyages*, III, pp. 64-66; H. W. Hill, *The Champlain Tercentenary*, Albany, 1911, p. 57.

[2] Manuel Orozco y Berra, *Apuntes para la historia de la geografia en México*, Mexico, 1881, pp. 423, 326.

[3] De La Condamine: *Relation abrégée d'un voyage fait dans l'intérieur de l'Amérique Méridionale.* Paris, 1745, p. 13 *et seq.*

for finding latitudes; finally he was ill when he descended the river to Para. One has only to read his manuscript journal, of which I have a copy, to see that many obstacles then and after his return to the mission did not permit him to make the observations necessary to make his map exact especially toward the lower part of the river."

The difference in longitude between two places can be found by noting the exact times of an event visible simultaneously at both places—an eclipse, for instance; the difference of these times gives easily the difference in longitude. If in an eclipse of the moon, the shadow of the earth is seen at one place to touch the moon at 9 P. M. and in another place at 10 P. M., the difference in time of the two places is one hour and the difference in longitude is one twenty-fourth of 360°, or 15°. This method goes back to the time of the Greek Hipparchus. But in early days the determinations of longitude were often absurdly inaccurate. When on his second voyage, Columbus observed at Haiti in September, 1494, an eclipse of the sun and made a calculation which placed him 18° or about 1,200 miles too far west.[4] On October 6, 1541, Antonio de Mendoza, first viceroy of New Spain (Mexico), wrote that by observing two lunar eclipses he had found the difference in time between Mexico City and Toledo in Spain to be 8 hours 2 minutes 34 seconds. This yields for Mexico[5] a longitude which is in excess of the true value of 25° 42′ 42″. This determination remained the accepted value during the sixteenth century. The eclipse of the moon of September 23, 1577, was observed in Mexico City and also by Tycho Brahe at Uraniburg, and by various astronomers in other places. From the data thus obtained it followed that Mexico City was 104° 45′ west of Paris—a very accurate figure for that time—being less than 4° in excess of the true value.[6] Other determinations were wider from the mark, so that the figure adopted for maps of about 1601 were 7° in excess of the true value. An eclipse of the moon was observed at Huehuetoca, situated in the same meridian as Mexico, on December 20, 1619, by the Dutch engineer Enrico Martinez. That eclipse was carefully observed in Europe and yielded greater precision of many geographical locations. The various observational data were gone over by Fray Diego Rodriguez of the University of Mexico, the immediate predecessor of the famous Cárlos de Sigüenza; Rodriguez reached the conclusion that the city of Mexico was 101° 27′ 30″ west of Paris.

[4] J. Winsor: *Narrative and Critical History of America*, Vol. II [1886], p. 99.

[5] Manuel Orozco y Berra, *op. cit.*, pp. 150, 151.

[6] Manuel Orozco y Berra, *op. cit.*, pp. 312, 313.

This result was very satisfactory for that time, exceeding in accuracy the value reached by Alexander von Humboldt about a century and a half later and differing by only 12 seconds of time from the modern figure of 101° 27′ 18″ due to Francisco Diaz Covarrúbias.[7] Rodriguez's determination of longitude did not become known in Europe, where geographers of the eighteenth century placed the longitude of Mexico as high as 106° and 107° 30′. The latitude of Mexico was fixed at the time of Cortés at 20°. Among the best eighteenth century determinations was that of Antonio Leon Gama. This modest but accomplished scientist was born and educated in Mexico. He studied the works of Newton, Wolf, Gravesande, Musschenbroek, the Bernoullis and Lacaille. He was connected with the school of mines in Mexico, calculated and observed eclipses of the sun, made determinations of longitudes and latitudes, and prepared a dissertation on the aurora borealis. He was highly esteemed by Lalande, who secured the publication of Gama's scientific results in the *Connoissance des temps* in Paris.

But eclipses of the sun and moon do not occur with sufficient frequency to satisfy all practical needs. Nor is the weather always propitious when eclipses do occur. If the two stations are far apart, one let us say at the Greenwich Observatory or at Paris, and the other somewhere in America, the comparison of time observations would meet with long delay (unless ephemeris are available) on account of the slowness of intercommunication in olden time. It was Galileo who, using his new telescope, discovered that Jupiter had moons, and he made the happy suggestion that they might be used in the determination of longitudes. These moons revolve about Jupiter and are part of the time in the cone of shadow cast by Jupiter. The moment when, let us say, the first satellite plunges into the shadow, can be observed in two places whose difference in longitude it is desired to ascertain. As this satellite revolves about Jupiter once in less than two days, there are plenty of opportunities for observation. Moreover, tables can be computed, giving the times of disappearance as seen in Paris or Greenwich, so that an observer in America possessing such a table, can compute the difference in longitude on the spot. If one observes the time of immersion of the satellite at Philadelphia, then finds in his table the Greenwich time of immersion, the difference of the two times gives the time-difference in longitude between Philadelphia and Greenwich, which can be easily translated into degrees. Unfortunately, considerable errors arise, because the moment of apparent disappearance into the shadow depends

[7] Manuel Orozco y Berra, *op. cit.*, pp. 221, 222, 312.

upon the size of the telescope used. By order of the French Academy of Sciences, Father Louis Feullée, a learned Franciscan and pupil of the astronomer G. D. Cassini, made observations of longitude and latitude in various places in Europe and America. He visited the Antilles and Panama in 1703-05, the western coast of South America in 1707-1712. His physical, mathematical and botanical observations were published at Paris in 1725.

Eclipses of the sun and moon were observed in the heart of South America, in distant Paraguay, by a missionary, F. Bonaventura Suarez.[8] He observed a solar eclipse on November 5, 1706, "with a five-foot telescope and a pendulum vibrating seconds, with an equal motion, and rectified to true time by the altitude of the fixt stars." In 1728 "a tube of 10 foot" was used; in 1729 the motions of the satellites of Jupiter were watched with a tube of 13 foot; there was a conjunction of the first and second satellites, so that "both stars seemed to be one." In 1767 the Jesuits were driven out of Paraguay, and astronomical work ceased.

Longitudes were obtained also from lunar observations and lunar tables. In any case, the accurate determination of longitude and latitude calls for accurate instruments. It is not surprising that early determinations were extremely crude. Even after the clock and telescope were available gross errors arose. As an example, we cite a French observation near the mouth of the Mississippi. The French King sent the Jesuit Father Antoine J. Laval, a man of long experience in astronomical observation, to the Mississippi region to gather data for improved navigation and better maps. Though valuable in other respects, his maps showed wrong longitudes. On July 24, 1720, Laval observed the time of immersion of Jupiter's first satellite at Dauphine Isle, an island near the Alabama coast, which yielded as the longitude of that island 103° and some minutes west of Paris. Claude Delisle[9] criticized Laval's work, pointing out that 103° exceeded the previous estimate of Pitergos by 4°, of van Keulen by 6½°, of Delisle himself by 11°. If one considers that at the equator one degree means about 69½ miles, it is apparent that the location of Dauphine Isle was uncertain to the extent of many hundred miles. The same uncertainty affected the longitude of other points on the Gulf Coast. As a matter of fact, all of the above estimates were in excess; Dauphine Isle is about 90° 30′ west of Paris. Humboldt once said[10]

[8] Astronomical data were communicated in 1747 to the Royal Society of London. See *Philosophical Transactions*, Abridged, Vol. 10, Part I, London, 1756, pp. 118-124.

[9] *Mémoires de l'académie royale des sciences*, année 1726, pp. 249-258.

[10] *Voyage de Humboldt et Bonpland*, Troisième Partie, Paris, 1811, p. V, foot-note.

that as late as 1770 the latitude of Dresden was three minutes in error, that of Mannheim in 1790 about one minute and twenty-one seconds. Errors in longitude usually exceeded those of latitude. It was not till about 1790 that much greater precision in astronomical measurement became possible through the invention and manufacture of high-grade repeating circles by English and French mechanicians.

That the determination of longitudes and latitudes was persisted in is evident from the fact that in 1784 and 1785[11] there was published at Berlin a table of longitudes and latitudes of 200 important points on the earth and that a dozen places in Central and South America were mentioned; however, all longitudes differed widely from modern determinations. The satellites of Jupiter were observed later by Alexander von Humboldt in his travels in South America.

2. *Comets.* Comets were a subject of attention and solicitude in the New World, as well as the Old. As early as 1653, Gabriel Lopez de Bonilla, an astronomer and mathematician in the city of Mexico, published[12] a "Discourse" on the comet that appeared in December of 1653. The famous comet of 1680 which seemed to approach dangerously near to the sun, was observed and discussed in Europe and America. A German Jesuit, Valentin Stansel, who had taught rhetoric and mathematics at Olmütz and Prague, later became attached to the Jesuit College of San Salvador (Bahia) in Brazil, where he took astronomical observations, particularly on comets. These observations were sent to Europe and published in Latin in 1683 at Prague. Notices of this book appeared in the *Acta eruditorum* of Leipzig of 1683.

At the city of Mexico a discussion took place on the comet which touched theological as well as scientific considerations. A scholar of wide reputation in his day was Cárlos de Sigüenza y Góngora, interested in mathematical, philosophical and antiquarian subjects. He was born in the city of Mexico[13] in 1645, devoted himself assiduously to intellectual pursuits and became professor of cosmography and mathematics at the Royal University of Mexico. He was the first to prepare a general map of Mexico. He published at Mexico in 1681 a *Manifiesto* intended to reassure the people that comets were not tokens of the wrath of heaven. His liberal

[11] J. E. Bode: *Astronomisches Jahrbuch für das Jahr 1784, 1785*, Berlin.

[12] "Discurso y relacion cometographia del repentino aborto de los Astros, que sucedió del Cometa que apareció por Diziembre de 1653," noted in D. Vicente Riva Palacio's *México á Través de los Siglos*, Tomo II, Mexico, Barcelona [1888-89], pp. 738, 739.

[13] J. T. Medina: *La Imprenta en Mexico* (1539-1821), Tomo II, Santiago de Chile, 1907, pp. 415, 416.

opinions were opposed by Martin de la Torre, a Flemish nobleman who in a pamphlet[14] upheld the old and popular view that comets were signs of approaching disaster. Sigüenza replied with a tract[15] on "Mathematical Bellerophontes against astrological Chimeras." There was published in the same year, 1681, also a "Discourse cometological" by Joseph de Escodar Salmeron y Castro. This author was medical professor at the University. To this strange document which made the declaration that the comet was an exhalation of dead bodies and of human perspiration, Sigüenza made no reply. Most prominent and able among the critics of Sigüenza was the Jesuit, Eusebio Francisco Kino, who had just arrived from Spain and later became a pioneer missionary explorer in California. Born at Trent in Trentino, Kino had studied in Germany and distinguished himself at Freiburg and Ingolstadt in mathematics. He refused the offer of a professorship in the University of Ingolstadt, to become a missionary to heathen lands.[16] While waiting for a chance to cross the Atlantic, he took observations at Cadiz on the comet of 1680. When he arrived in Mexico he at once entered into the public discussion started by Sigüenza. Kino published at Mexico in 1681 a pamphlet under the title: "Astronomical Explanation of the Comet" presenting an able argument but using a tone not altogether free of arrogance. Sigüenza prepared a reply touching theologic and scientific questions. It was written in 1681 but did not appear in print until 1690. It was entitled *Libra astronómica y philosofica*, a title which Father Orazio Grassi had used in a reply to Galileo on the Comet of 1618. The prologue of the book was written by a hydrographer of high standing in Mexico, Don Sebastian de Guzman, a pupil of the learned mathematician, Ruesta. This prologue indicates some of the scientific questions that came under discussion, questions of parallax, of astronomical refraction, of whether the paths of comets were rectilinear as had been claimed by Kepler or a conic or helixes formed in accordance with Descartes' theory of vortices. Sigüenza challenged the reliability of Kino's observations, on the ground that the comet of the year 1680 could not be observed with accuracy in Europe because of its great declination and of its appearance in twilight.[17] Another publication on comets, from the pen of Gaspar Evelino[18] appeared at Mexico in 1682.

14 "Manifiesto Christiano en favor de los Cometas mantenidos en su natural significacion." See *México á Través de los Siglos*, Tomo II, p. 739.

15 "Belerofonte Mathematico contra la chimera astrologica." See Vol. II, p. 739, of *México á Través de los Siglos.*

16 H. E. Bolton: *Kino's Historical Memoir of Pimería Alta*, Vol. I, Cleveland, 1919, Introduction, p. 29.

17 Jose Mariano Beristain y Souza, *Biblioteca Hispano Americana Seten-*

We have dwelt at some length upon Sigüenza and his controversy on comets, because this debate is the earliest instance of a clash of intellects in public print on a scientific question that occurred in America. This controversy, conducted in a region far remote from the recognized centers of intellectual life, was very creditable and indicated that even distant America affords examples where in the seventeenth century the scientific method was arrayed in battle against the antiquated processes of theology and superstition.

3. *The earliest permanent observatory in America.* The city of Bogata in New Granada (the present Colombia) had the reputation of being "the Athens of South America;" it was the seat of scientific activity at the close of the eighteenth century. A Spanish scholar, José Celestino Mutis, assumed in 1762 the chair of Mathematics and Astronomy in the Colegio del Rosario, but the chief effort of his life in Bogota was botany. Noted is his study of Cinchona bark, the source of quinine. He was the first to teach the Copernican system in New Granada; he observed the hourly variations of the barometer. He took astronomical observations, but unfortunately never published them. He and Alexander von Humboldt were great friends. That his early interest in astronomy did not wane is evident from the fact that he founded an observatory in 1803[19] and became its first director. He trained many scientists, notably Francisco José de Caldas, who was in charge of the observatory for eight years after the death of Mutis in 1808, and then became a martyr in the cause of New Granada's independence from Spain. The claim that the astronomical observatory of Bogota is the earliest in America seems valid. We know that David Rittenhouse had an observatory at Norriton, near Philadelphia, for the observation of the transit of Venus in 1769, but that observatory was not permanent. The observatory at Bogota has not been in continuous use, nor did it contribute in any notable way to the progress of science. We are informed that in 1823 it was "absolutely abandoned,"[20] as was also the botanical garden at Bogota, but in later descriptions of Bogota the observatory is mentioned.

trional, 2 Ed., Tomo II, Amecameca, 1883, p. 127; Tomo III, p. 145. Several long quotations from the *Libra astronómica y philosofica* relating to longitudes, are found in Manuel Orozco y Berra's *Apuntes para la historia de la geografia*, 1881, p. 218-221.

18 Manuel Orozco y Berra, *op. cit.*, p. 219.

19 Carlos Navarro y Lamarca, *Compendio de la Historia general de América*, Buenos Aires, 1913, Tomo II, p. 308.

20 Gaspard Théodore, Comte de Mollien, *Voyage dans la république de Colombia en 1823*, 2 Ed., Tome I, Paris, 1825, p. 282.

4. *Atmospheric refraction.* Ptolemy was the first to notice that light from a star undergoes a change in direction as it enters the earth's atmosphere, but no attempt was made to correct apparent positions of the celestial bodies before Tycho Brahe whose table of refractions was very imperfect. The law of refraction of light was first discovered by W. Snell in 1637. He showed that the sines of the angles of incidence and refraction bear a constant ratio to each other. The application of this to the atmosphere was far from easy. G. D. Cassini published tables in 1662 which corrected for the combined influence of parallax and refraction. But it became desirable to know the independent effects of these two elements. Jean Picard remarked in 1669 that probably refractions vary with the season of the year, and the different changes of the weather. Strangely Picard and Cassini thought they had reason to believe that refraction at the polar circle was double that at the parallel of Paris.[21] To explain the difference between these refractions of tropical regions and the temperate zone Bouguer set up the hypothesis that the nature of the atmosphere varied with the climate. Voyages were undertaken to determine altitudes above sea-level. Cayenne, the Cape of Good Hope, Quito, places in India were visited at different times by J. Richer, N. L. Lacaille, Bouguer and Legentil. The true explanation, to the effect that refraction is dependent upon atmospheric temperature and pressure, was advanced by Tobias Mayer and Lacaille, so that it is possible to construct tables of refraction which can be used in all climates and all parts of the world. Finally the observations made by Alexander von Humboldt during his travels in South America during the initial years of the nineteenth century helped to clear up this question. Our reference to Richer must be supplemented by the remarks that when in 1672 he was at Cayenne in Peru, he secured data on Mars for determining the parallax and he also made the notable observation that a pendulum adjusted at Paris to beat seconds lost at Cayenne two minutes daily. This observation bore on the then mooted question of the flattening of the earth.

5. *Meridian measurements for determining the shape and size of the earth.* Two meridian measurements were made in America during the eighteenth century, one in South America and one (by Mason and Dixon) in North America. Such projects require the greatest care and skill, as well as instruments of the highest degree of perfection obtainable. It is not surprising that both were carried out by men of European training. The earlier, which has been

21 Voiron, *Histoire de l'Astronomie depuis 1781 jusqu'à 1811.* Paris, 1810, pp. 57, 58.

found the more valuable, was conducted in Peru, in the years 1735-1739, by Louis Godin, Pierre Bouguer and Charles-Marie De la Condamine, under the auspices of the French Royal Academy of Sciences, working in conjunction with two Spanish officers, Don George Juan and Don Antonio de Ulloa. While on their way, on the western coast of Ecuador, Bouguer and De la Condamine determined the position of the equator and chiseled upon the rocks an inscription to that effect. The plain north of Quito was chosen as best suited to base measurements; stations for triangulation were selected on the rugged mountains which hem in the valley in which Quito is situated. This Peru arc plays an important rôle in the early history of meridian measurements.

6. *The transit of Venus of 1769.* The transit of Venus over the disc of the sun in 1769 attracted a very great deal of attention in Europe, in the American colonies in North America, as well as in South America. In Philadelphia and Boston elaborate preparation were made for observing the event. In the city of Mexico it was observed by Father José Antonio Alzate, a most zealous student of the natural sciences in New Spain, who sent his observations to Paris, where they appeared in 1770.

A French expedition was made under the auspices of the French Academy of Sciences.[22] The observations were taken by Jean Chappe d'Auteroche at the Mission of San Joseph, located at the extreme southern terminus of Lower California, also by a Spanish actronomer.[23] Chappe's equipment comprised as the principal instruments a quadrant of three-foot radius, a transit instrument, an achromatic telescope of ten feet and another of three feet that were both constructed by Dollond in London, and a pendulum clock of Berthoud. On the morning of the eventful day, June 3, Chappe used in his preliminary observations only his left eye, saving his right eye for the important observations that came later. To his great joy, the observations were very successful. His position was one of the most favorable for data for the determination of the parallax of the sun. An epidemic was raging in the village; Chappe did all he could to alleviate suffering, but himself contracted the disease. Though ill, he successfully observed the eclipse of the moon on June 18, 1769. He died on August 1, a victim of the epidemic.

7. *Scientific periodicals.* The honor of having started scientific periodicals in the eighteenth century in New Spain belongs to José Antonio Alzate and Ignacio Bartolade. The latter started in

[22] *Philosophical Transactions*, Vol. 60, for the year 1770, London, 1771, p. 551.

[23] *Loc. cit.*, p. 549.

Mexico city the *Mercurio Volante* in 1772 which gave curious and important notices upon various matters in physics and medicine. It had an ephemeral existence. Alzate began in 1768 the *Diario literario de Mexico* which was soon suppressed, but it reappeared under a new title, to be again suppressed after eleven numbers had been issued, only to spring into existence a third time in 1787 under another name and going through fourteen issues. In 1788 the famous monthly, *Gaceta de Literatura de México* was started and it continued, though with some irregularity, until 1799, as a literary and scientific review. We have seen in it notices of experimental research conducted by Franklin, Lavoisier and others. Alzate himself took many astronomical and meteorological observations.

8. *Conclusion.* This rapid survey gives indication of early scientific activity worthy of systematic record. That much of it was the product of European talent is not surprising. That some of it represented the achievement of men born and educated in America is a source of satisfaction. The quality of work was mainly observational, consisting of the gathering of data on eclipses, transits, parallaxes, comets, meteorology, altitudes of celestial bodies, pendulum experiments, geodetic base measurement and atmospheric refraction. The applications of these data to scientific theory were made in the scientific centers of Europe where the data from different parts of the world could be gathered. Except for Sigüenza's general map of Mexico, the more important of the early maps were prepared in Europe by C. Delisle, G. B. Riccioli and others. The study of the shape and size of the earth and the preparation of tables of correction for astronomical refraction were made by astronomers in the old world. Nevertheless, even before the nineteenth century, America, though merely a distant outpost, was an integral part of the field of operations of the great army of scientific workers.

.THE AGE OF THE EARTH[1]

By Professor JOHN JOLY, D.Sc. F.R.S.

"THE Age of the Earth" is a somewhat ambiguous phrase. From the geological point of view it is generally understood to mean the age of the ocean: in other words, the age of the earth since the beginning of those geological surface changes which are due to denudation. But another meaning may be ascribed to the term. We may assume the beginning to date from the cooling of a highly heated surface to the point of solidification. In this case we include in the age those long periods of Archæan time during which the activity of water played a subordinate part and volcanic commotion prevailed among the semi-fluid, rocky constituents of the globe. Yet a third interpretation refers the birth time to a still more remote and indefinite epoch when the world become differentiated as a planet by activities, of the nature of which we are ignorant. Astronomical deductions and speculations regarding the age are mainly concerned with the last period.

What I have to say will be restricted, almost entirely, to the first interpretation of the term. I mean by the age of the earth the period which has elapsed since its surface became the scene of world-wide denudative forces and the foundations of organic evolution were laid.

In virtue of these denudative forces we find ourselves possessed of certain methods of estimating the age which are valid upon the assumption that denudation proceeds in our time at a rate not greatly differing from its mean rate over geological time. The bases of this assumption are as follows:

(*a*) That the chief factor in denudative activity being the rain supply falling on the land, solar heat and atmospheric circulation are primary causes. The life on the globe since very early times and the narrow temperature limits conditioning protoplasmic existence and activity show that great extremes of solar radiation can not have affected denudation for long periods in the past. Mere climatal extremes do not sensibly affect solvent denudation. Atmospheric circulation, being largely conditioned by the earth's rotation and the distribution of solar heat, can not have varied to any effective extent.

[1] Address before the Royal Institution of Great Britain.

(*b*) That a considerable percentage of the existing land area being rainless, changes in continental area can not greatly affect the amount of denudation: the belt undergoing denudation being merely displaced outwards or inwards. The evidence derived from paleography and from the extent of sedimentary deposits in all ages shows that the present land area is not greatly different from the past mean area.

(*c*) That the minor factors affecting solvent and detrital denudation being very many and of very different characters are unlikely to combine at any time, and for any long period, in one direction, so as to create a considerable departure from the mean.

Time will not permit a discussion of these statements. I shall refer but briefly to the methods by which the statistics of solvent and detrital denudation are used to afford the age of the ocean.

(1) The chemistry of the ocean and of the rocks is the key to our position. As the result of a comparative study of the primary or igneous rocks, and the secondary or sedimentary rocks, we find that, say, n grams of sodium are shed into the ocean for each ton of igneous rock converted into sedimentary rock, and in the ocean we find N grams of sodium. The total denudation over geological time has, therefore, been N/n expressed in tons of denuded igneous rock. Our study also tells us the average total loss attending the conversion of the primary rock into sediment, and so we get the total of the secondary rocks in tons. We now go to the principal rivers of the world, and availing ourselves of estimates which have been made of the amounts of sediment—*i. e.*, of secondary rock material—which they transport from the land in a year, we calculate the number of years it would take to lay down in the ocean the great mass of sediment generated in the past ages. After certain allowances this comes out at about 100 million years.

(2) Again the total of oceanic sodium may give us the age in another and more direct way. We know that by far the greater part of this sodium was carried into it by the rivers during geological time. We turn to the analyses of river water and estimate the total annual supply of this element to the ocean. Dividing the latter into the former and making certain allowances we find an age which is about 100 million years.

(3) A third and more difficult method is independent of our knowledge of chemical denudation. We estimate the maximum thickness of the integral sedimentary deposits, and knowing the burthen of sediment conveyed per annum by the rivers, we estimate the maximum thickness of deposit annually derived from the same; we divide the latter into the former and find an age which, again, is about 100 million years.

Of these methods, that which involves the sodium modulus only

is the most direct. Of course the reason for selecting this particular element as a modulus is because of its great solubility, on account of which it alone among the dissolved oceanic constituents has been preserved from organic abstraction or chemical precipitation. This method has been examined by many critics. Notably by Sollas, who, in a presidential address to the Geological Society in 1909, subjects it to searching examination. He concludes that a period of 175 millions of years may be reached upon certain assumptions, and that this must be very nearly the maximum allowable. My own examination of this method has led me to believe that it is *possible* that 150 millions of years may be indicated by it, and that 200 millions of years would not be reconcilable with our present knowledge of the factors involved. This would, as I have already stated, apply only to the duration of sedimentation. It can not be compared with data which apply to an age dating back into the Archæan.

There was, indeed, some scanty sedimentation in Archæan times. We can not form any estimate of its effects upon our numerator or upon our denominator save that we seem entitled to conclude that they were small. "The Archæan was essentially a period of world-wide vulcanism, and in the relative proportion of rocks of igneous and sedimentary origin represents a departure from the uniformity of conditions of later geological time." I quote from the monograph of Vane Hise and Leith.

Before passing on to the results based upon radio-activity I must refer to one point in particular which has been urged against accepting present-day rates of denudation as a basis of time measurement. It is said we live in a period of abnormal continental elevation which, it is asserted, involves excessive solvent denudation. A little attention to the nature and conditions of solvent denudation should have sufficed to forestall the argument. But a ready method of dealing with it is available. The continent of North America has a mean elevation of 700 metres: it is being denuded at the rate of 79 tons per square mile per annum; for South America the corresponding figures are 650 metres and 50 tons. Now Europe has a much lower mean elevation—300 metres. Its rate of denudation is, however, 100 tons per square mile per annum. The rate of solvent denudation is, in fact, by measurement found to be *less* for the more elevated land, as theoretically it should be. The argument then, if it has any basis, would indicate that the age as found from solvent denudation is excessive.

Prior to the advent of those methods for investigating the earth's age, which are based on radio-active changes in the elements, no serious objections to the results reached by the geological methods were raised, so far as I know. There were some, indeed,

who regarded the age as excessive. Thus Becker arrived at a lesser figure by taking into account the progressive impoverishment of the surface materials during geological time. The validity of the correction is, however, open to doubt. Others considered that the organic changes recorded in the rocks required a longer period. Sollas gave, as I think, a clear answer to this objection in his "Age of the Earth." Both Lyell and Geikie, and Poulton, had in past years upheld the doctrine of Uniformity. But the advent of the radio-active method, as founded on the uranium family of elements, seemed to point to a vastly greater age; leading, in fact, to the extraordinary conclusion that the present rate of solvent denudation is not less than four times, and may be eight (or even more) times, in excess of the average rate obtaining during the past.

The earliest suggestion of the possibility of using the stored-up products of radio-active change came from Rutherford. He, and later Strutt (now Lord Rayleigh), applied the accumulation of helium to the evaluation of geological time. Strutt laid out a geological chronology, the first of its kind, but considered he was dealing with minor limits. Boltwood used the residual product of uranium—lead—and for Archæan (?) materials reached as much as 1640 million years. As I have already said, the denudative method can not be regarded as extending to those remote times. But such results as 480×10^6 years for Silurian or Ordovician deposits, and 1200×10^6 years for Post-Jatulian, are quite out of harmony with the denudative method. To-day the matter stands thus: A number of results are available based upon the use of carefully selected material, and when the material is thus selected the ratio of lead to uranium—the "lead ratio" as it is termed—increases as we go downwards and diminishes as we go upwards in the strata, preserving a fair degree of agreement even for widely separated localities.

Those who would rest content with this result, however, can do so only by ignoring the very interesting and suggestive fact that when we base the results on the lead ratio of selected thorium minerals, we arrive at ages which are in substantial agreement with the results reached by the denudative method. On the face of it this agreement gives strong support to the conclusions reached by methods absolutely different in nature.

For long it was known that thorium minerals—such as thorite—gave persistently lower ages than uranium minerals. It became the custom with some to treat these ages as untrustworthy. But we know now that this attitude is not justified, but rather that the onus of explaining away the impressive agreement between the indications of thorium lead and denudative statistics rests with those who would reject the age supported by both.

Soddy's determination of the atomic weight of the thorium lead isotope in 1917 afforded material for an age determination on a very large scale, and from the nature of the research, one of special value. The material was a thorite from Ceylon; from rocks immediately overlying the Charnockite series. The latter is extremely ancient—Lewisian or Lower Archæan. Upon reading in *Nature* Professor Soddy's account of his determination of the atomic weight of the lead derived from these rocks, I estimated that the quantity of lead extracted from the thorite gave an age of 130 millions of years for the time since this mineral had been generated; and on communicating with Professor Soddy I found that he had reached a somewhat similar conclusion.

At this time, however, there was the possibility that thorium lead was not altogether stable. Suspicion fell more especially on thallium as the final product. Two experimental results, however, laid this doubt to rest; experiments upon a thorianite made in my laboratory by J. R. Cotter failed to detect even spectroscopic traces of this element, and there was insufficient thallium found in the thorite dealt with by Professor Soddy. In a subsequent letter to *Nature* Professor Soddy states that a research carried out at the Radium Institute of Vienna supported the view that the lead isotopes derived from thorium were both stable. I shall refer presently to yet additional evidence that the transformations of the thorium family cease with lead.

Writing to *Nature* in support of the hypothesis then under discussion—*i. e.*, that thorium lead was unstable—A. Holmes cited a result on a selected specimen of uraninite, showing that the rocks in which Soddy's thorite occurred were, according to the uranium-lead ratio, 512 millions of years old. Previous uranium-lead ratios had assigned a much greater age to them. Here, then, the results join issue: the uranium result is just four times as great as the thorium. We notice, too, that on the uranium-scale of time this thorite must be older than Silurian or Ordovician, which have been determined by uranium lead as 430 millions of years ago. Probably its age dates back to Cambrian or even to pre-Cambrian time. From what we have already inferred we can not regard 130 millions of years for early Palæozoic times as irreconcilable with the maxima which denudative methods afford. More recently, lead derived from a Norwegian thorite of Langesundfiord—also of lower Palæozoic age—seems to reveal an age of 150 millions of years. In this case, also, there is the added security of a determination of the atomic weight of the lead.

We can not discredit these results on the score of radio-active instability of the lead. Why, then, set them aside in favor of results reached on uranium lead, which are in hopeless contradiction

to the indications of the record of the surface activities of the globe? It is, indeed, not too much to say that the whole position is now reversed, and that to-day suspicion attaches to the uranium-lead ratio. And, as we shall see, there is much unknown about the earlier radio-active sequence in the uranium series, while the discovery of isotopes opens the way to possibilities unthought of in the earlier days of radio-active science.

I shall, however, now turn to the evidence of the pleochroic halo on this matter.

The halo affords a means of investigating certain facts respecting the break-up of the radio-active elements in the remote past. For the dimensions of the halo—minute though they be—can be determined with considerable accuracy, and these dimensions are conditioned by the added effects of the several α-rays emitted by the transmuting elements. Bragg and Kleeman observed and measured just such integral ionization effects in air. In the rocks the ionization curves, owing to the great stopping power of minerals, are on a scale 2,000 times as small. They are very faithful hieroglyphics, however, and carry back our knowledge over an appalling vista of time.

One single α-ray produces a well-known curve of ionization determined by Geiger. The range of the rays does not affect the general nature of the curve. If we imagine uranium or thorium as parent elements contained in a minute crystal—of zircon, for instance—we must picture the various α-rays affecting the surrounding substance—mica, we may suppose—in such a way as to build up concentric spherical shells more or less overlapping and corresponding to the radial distances at which the ionization of the several rays is at a maximum. As seen in section upon cleaved flakes of the mica, we find concentric colored rings representing the ionization due to the rays.

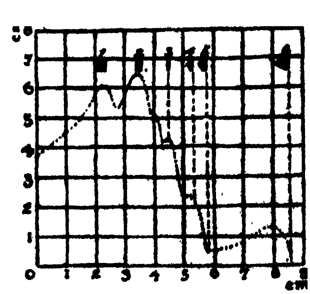


FIG. 1

In order to arrive at the theoretical location of these rings we must add up the several ionization effects as observed in air. This involves assigning a Geiger curve to each ray according to its range and adding up the ordinates.

Let us consider first the case of the thorium halo. Fig. 1 is a curve arrived at in the manner I have just described. Its ordinates are proportional to the integral ionization effects of those radio-active elements in the thorium series which emit α-rays. And above it I have marked, calculated into the range in air, the positions of

the colored rings which in biotite we observe encircling a minute mineral particle containing thorium and all the successive products of its transmutation. This, of course, necessitates magnifying the halo enormously—rather more than 2,000 diameters. You perceive that the halo very faithfully conforms to the features of the air-curve. It may be of interest to mention that the finding of the third ring led to the discovery of the prominence on the curve which accounts for it. This part of the curve had originally been plotted from an insufficient number of ordinates. This close agreement really reveals a very important fact. The air-curve depends for its dimensions on the ranges of the several α-rays as we measure them to-day in the laboratory. The halo-measurements refer to radio-active effects which began their record in this mica in Carboniferous times—possibly long before. The halo reveals no sign of change in the several ranges concerned. As you are aware, the rate of break up, the transformation constant of the element, is related to the range. We are, therefore, in the case of the thorium family, entitled to read in these minute and ancient records a guarantee that the accumulation of the final product—the thorium isotopes of lead—was in the remote past affected at just such a rate as we have inferred from the splendid researches of our day. The thorium halo gives us this guarantee. It also tells us that it is improbable that the resulting lead is unstable. For if it were we must find room for rays additional to those we have used in deriving the ionization curve. True, a coincidence of range might enable a ray to lie concealed in the halo; but the fit of the halo is so absolutely faithful to every feature of the curve that this seems improbable.

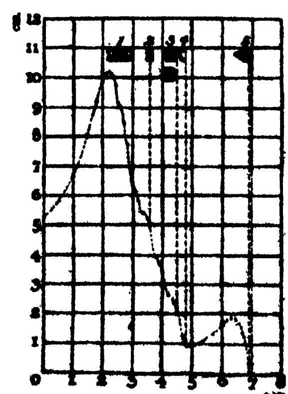


FIG.

It is also possible to observe the successive stages of development in thorium haloes. The first rings to appear are those corresponding to the two conspicuous crests of the curve, Fig. 1. If the central nucleus is small or feeble, nothing more may be developed.

We now turn to the uranium curve. The eight contributory ionization curves are placed according to the range of each ray, and Fig. 2 shows the curve produced by adding up the ordinates. Above it are laid out the several rings observed in the uranium halo. Looking at these rings, we notice that the outer features of the halo seem in fair agreement with the present-day ranges. But the innermost ring has a larger radius than would

be expected from the curve. Much care has been expended in verifying this point. In the Devonian mica of County Carlow these haloes are found in every stage of development according to the size or activity of the nucleus. The uranium halo begins as a single delicate ring surrounding the minute central nucleus. It can be measured from a stage bordering on invisibility to a stage when its central area is beginning to darken up and the first shadowy signs of the outermost ring of all—that due solely to radium C—appear. A large number of readings on these embryonic haloes, made recently by various observers, confirm the mean value of its radius as cited in a paper communicated to the Royal Society in 1916. The discrepancy with the theoretic curve is small: 10 or 12 per cent. of the external radius. The allowance for, and measurement of, the nucleus is sufficiently difficult to introduce some uncertainty.

This misfit may be of considerable significance. I have already reminded you that the range of the α-ray emitted by a transforming element is related to its rate of break-up. The range is longer for the shorter-lived elements. Now, here the first ring of the uranium halo in mica shows a longer range than we would expect from the air-curve as observed to-day. The agreement between the two in other cases appears to show that this is not due to any unknown effect influencing the retardation in mica. The location of the first uranium ring is mainly referable to those short-range α-rays arising from the initial transformations of the uranium series. We infer that one or more of these rays must have had a longer range in past times, and, of course, that the corresponding transformation periods must have been shorter. A specially influential ray is that slowest of all the rays—that which is emitted in the break-up of uranium 1. The discrepancy might be due to this ray possessing a greater range in early geological times. But, whatever the cause, the nature of the misfit suggests evidently that formerly the rate of transformation of uranium to lead was faster than it is to-day.

It is with some reserve that I refer here to measurements made lately on haloes of comparatively recent and of very remote geological ages. I say "with reserve," for not only are the results of a nature calling for very adequate confirmation, but the measurements present considerable difficulty. The point at issue may be stated in a few words: Is the abnormality observed in the dimensions of the uranium halo dependent in amount upon the antiquity of the rock in which the halo is developed?

I had sought occasionally for uranium haloes in rocks younger than the Leinster granite—which is of early Devonian age. The granite of Mourne, which is of Eocene or early Tertiary age, for

long refused to reveal any haloes suitable for measurement. However, recently I was so fortunate as to find a few of these early halo rings which I was able to measure. Further search has revealed a few more; but they are excessively scarce and rather difficult to detect. The nuclei of these haloes are only rarely zircon—they seem to be apatite; possibly allanite—and their average size is greater than the zircon nuclei of the Carlow mica. Both the mineral nature of the Mourne nuclei and their dimensions involve, therefore, a bigger subtractive correction on the observed radius than is required in the case of the Carlow haloes. But in addition to this, there appears to be a small difference in the external radius of the Eocene halo and that of the Devonian halo. According to a large number of readings by several observers, some of whom were not acquainted with the question at issue, the external radius of the Eocene halo-ring—no allowance being made for the nuclear radius—is 0·0135 mm. The same observers obtained for the Devonian halo 0·0146 mm.—without allowance for the nucleus. The nuclear correction, as I have said, would have increased the discrepancy, but the correction is a difficult one. There is no reason to believe that *more* than 1 per cent. of this difference can be ascribed to the chemical composition or density of the micas, both of which have been investigated.

Still more recently I have found these primary ring-haloes in the micas of Arendal and Yitterby, which are said to be of Archæan age, and which are certainly extremely ancient. These haloes appear to possess a radial dimension of 0·0160 mm., or a little less. Here, again, the nature of the mica does not appear to be responsible. According to these measurements it would appear that the radius of the Eocene halo-ring must be increased by about 7 per cent. to attain the size of the Devonian halo-ring, and that this is, in radial dimension about 10 per cent. smaller than the Archæan. It would seem as if we might determine a geological chronology on the dimension of these halo rings!

The foregoing results, if confirmed, would give strong support to the view that some factor, variable over geological time, had affected the ranges and periods of certain elements concerned in building up the uranium halo. However, too much stress must not be placed on these measurements till they are confirmed by haloes in yet other micas. Pending further investigations, I return to the fact that the uranium halo of Devonian age does not conform to the ionization curve of the uranium family as determined on present-day measurements. Serious discrepancy seems confined to the shorter ranges, more especially with that primary range which is most influential in determining the rate of production of uranium lead.

We do not appear to be in a position to deny the possibility that uranium 1 may have slowed down in its rate of decay over geological time. Such laboratory observations as can be extended to the case of short-lived elements would not, probably, shed any light on the matter. It is a possibility long ago suggested by Rutherford. But if this is the explanation we must admit that in the case of thorium any corresponding effect must have been much smaller. On the whole the former influence of one or more isotopes of uranium—which possibly may almost have disappeared—seems the more probable explanation. Hypothetical isotopes of uranium have been invoked by highly competent authorities to meet the difficulties affecting the ionization accounts of the uranium family of elements. Boltwood suggests as "not impossible" that what we now call uranium consists of three radio-elements: a parent element and two isotopic products all emitting α-rays.[2] In 1917 A, Piccard put forward the view that the parent of actinium is a third isotope of uranium not belonging to the uranium family and having an atomic weight of 240. This view is regarded favorably by Soddy and Cranston. It clears up the difficulty respecting the atomic weight of uranium, and fits in with the atomic weights of radium and of uranium lead. Soddy and Cranston remark that in order to explain, in this case, the constant ratio of actinium to uranium observed in minerals we must suppose the period of uranium 1 and of the hypothetical isotope to be the same. This difficulty, however, is removed if we may assume that the ratio varied over geological time.

A somewhat similar theory to Piccard's may be invoked to explain the abnormality of the Devonian uranium halo. We have these facts to go on: The age indicated by uranium for Lower or Pre-Palæozoic rocks is about four times too great as compared with the age indicated by thorium. We assume, therefore, that three fourths of the lead as measured in uranium minerals is derived from a certain isotope. This isotope, not having been detected in our time by its primary α-radiation, we must suppose to be now sensibly exhausted. We, therefore, have a known mass of this isotope transforming to lead in a known time —130×10^6 years. Assuming that only 1 per cent. of it is left we get its transformation constant ($3 \cdot 5 \times 10^{-8}$), and by Geiger and Nutall's relation we find the corresponding range as 2·6 cms. at 0° C.; or about 2·75 cms. at 15° C. To-day the α-radiation of the hypothetical body would be only 1/1000 of that due to uranium 1, but during the period since the Devonian there will be about three α-rays from the short-lived isotope to one from the long-lived. The integral curve of ionisation

[2] *Phil. Mag.*, 6 S., Vol. XL, p. 50, 1920.

as modified by these hypothetical results would be in agreement with the Devonian halo. We have to assume that the ranges of the rays emitted by the successive disintegrating products of the supposed isotope were such as to leave the outer features of the halo sensibly undisturbed. This seems not improbable.

The salient features which appear in the study of radio-active haloes are: Firstly, that the agreement of our laboratory measurements of to-day with the features of the Palæozoic thorium halo is such as to support the view that the periods of the several elements concerned in its genesis have remained unchanged over 130 millions of years. This fact, taken along with the stability of thorium lead, seems to render its reading of geological time authentic in a high degree. Its indications are confirmed by the consistent testimony of the denudative processes which have progressed on the earth's surface. Secondly, it appears that the uranium halo is not in conformity with the period we ascribe to-day to uranium—a disagreement which is emphasized by the failure of uranium-time to conform with the united testimony of thorium-time and denudative-time; as well as by much that remains unexplained respecting the earlier changes in the uranium family elements.

The complete tale is not yet told, but I think the balance of probability is in favor of an age between 150 and 200 millions of years for the earliest advent of geological conditions upon the globe.

Astronomical investigation on the subject of the age of the earth deals, generally, with that greater age which must be ascribed to the earth as a planet. For this age vast periods have been claimed. But it is possible to reconcile superior ages for the earth as a planet with comparatively brief geological time. And, to my mind, in doing so we proceed upon what is no more than a necessary deduction based on our knowledge of the radio-activity of terrestrial materials. I would go further—still, as I believe, logically—and ascribe to radio-active energy an influence on planetary and stellar evolution much greater than has hitherto been admitted.

The only planet we can investigate at all closely is, of course, our earth. And what do we find? In its surface materials there are sufficient of the radio-active elements, as Lord Rayleigh first showed, to account for the observed average temperature gradient if the surface conditions extend a little way, about 19 kilometers, inwards. It is, for many reasons, in the highest degree improbable that such a definitely defined radio-active layer exists. Nor is it probable that the earth's interior is free from radio-active substances. We find both uranium and thorium in meteorites containing a large percentage of iron and nickel, and, although they have

not as yet been found in meteoric iron, we know from the mean density of the earth that its interior can not be composed of pure iron. It is probable that a considerable proportion (some 40 per cent.) of silicious materials are intermingled; and when such exists in meteorites invariably we find the radio-active elements. By what conceivable activity was all the uranium and thorium separated out and brought to the surface?

The view that radio-active elements exist in the earth's interior is sometimes met by a formal denial that the earth can be getting hotter within. Upon what evidence is this denial based? If the central core of the earth for a radial distance of 2,000 kilometres, say, had risen in temperature by 1,000° C. over geological time—and upon a low assumption of the interior radio-activity it might reach this temperature in 150 million years—would we be aware of the fact? Would the day be appreciably lengthened? Would there be any effect at all if the outer parts were cooling due to loss of primal heat? We have further to consider that only over the short period of historical time would any observations be available. The denial is quite baseless so far as my estimates go.

Well, then, if our earth is heating up within, is there not an impending termination to our geological age? Kelvin showed how complete is the thermal isolation of the earth's interior, and it is certain that interior heat is not now escaping. The rise of temperature within must go on till the present epoch succumbs to the accumulated energy. Then must ensue a period of vulcanicity which will end life upon the globe, and probably reverse the chemical work stored up by ages of denudative and organic activity. The whole sequence of events—rapid cooling by radiation, restoration of the oceans, and, possibly, re-birth of life and of its evolutionary history—would begin all over again. On this view the age we have been studying may be one of many, and will inevitably attain its three score and ten, terminating in labor and sorrow. But there must come a rejuvenation, and the rejuvenation, possibly, may one day be pondered by other minds than ours. Remember that after some ten thousand millions of years there still survives 50 per cent. of the heat-generating elements, and the effect of their diminution is only to lengthen out the recurring geological ages. Our planetary companions may be in various stages of such cyclical changes.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

AN INVENTORY OF ENERGY

By Dr. Edwin E. Slosson,
Science Service, Washington.

Our modern civilization has been developed by the lavish expenditure of the potential energy accumulated in the form of fossil fuel during geologic ages. Our wealth and industries, our comforts and luxuries, our science and art, our power and population, all are dependent upon the continuance of an adequate supply of energy from some source.

But the sources on which we are now relying, coal, oil and gas, are being rapidly used up and are irreplaceable. Natural gas is almost exhausted. Gasoline production is about at its peak. Of coal the United States has enough for five thousand years, but many countries have not any.

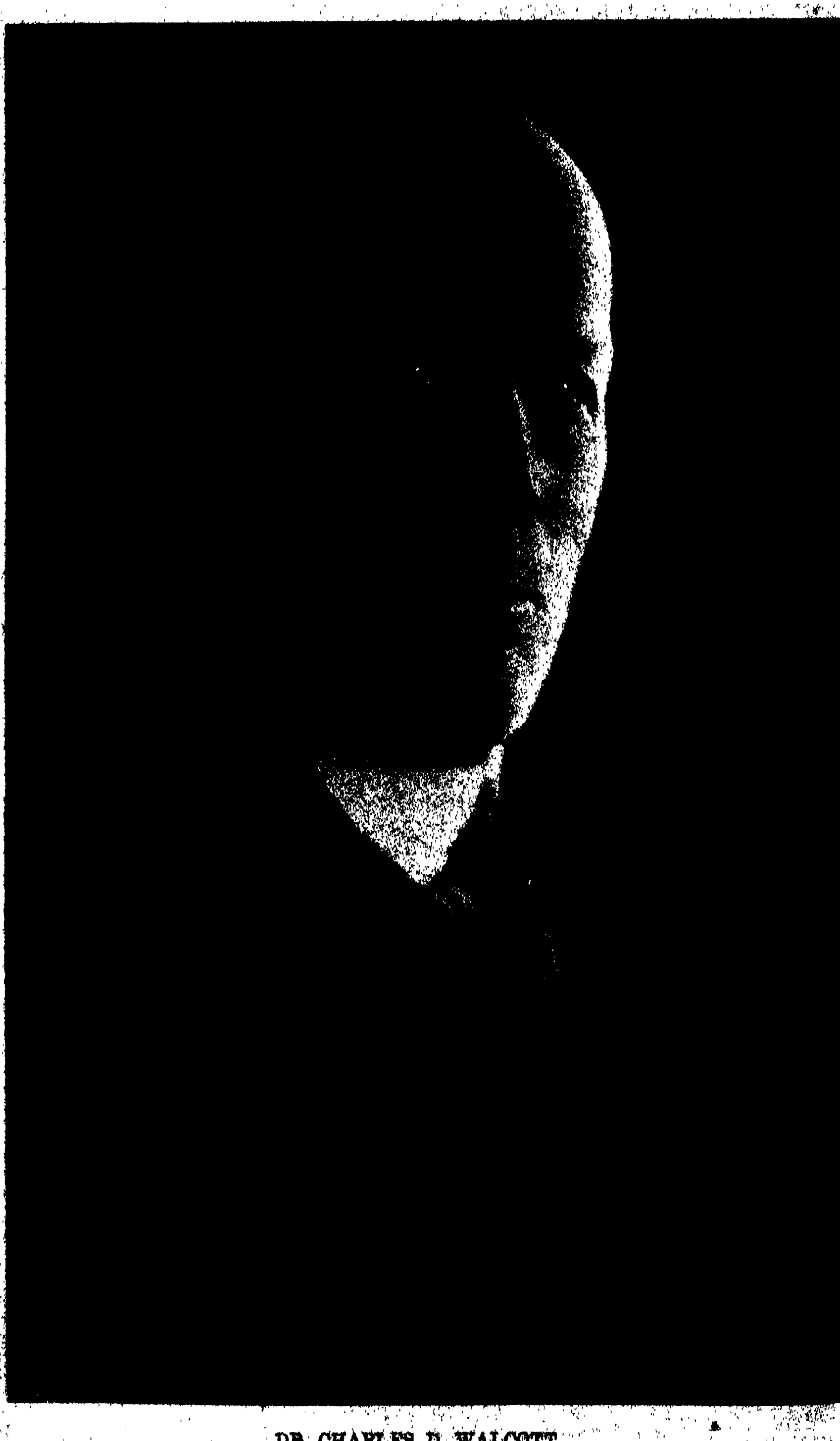
It is high time the world took stock of all conceivable sources of mechanical power to determine how far civilization may be developed or how long it may be maintained at the present level. Such an inventory would require the cooperation of the scientists and engineers of all nations in an investigation lasting many years. But fortunately the means of such cooperation now exist for the first time in the International Research Council which at its last meeting in Brussels last July took under consideration this project. The question was also discussed at the Boston meeting of the American Association for the Advancement of Science the last week of the year.

Popular confidence that "science will find a way" before there is any serious shortage is flattering—but unfounded. If we try to list all the sources of energy that we can think of we shall find that none of them is yet available or certain ever to be secured in adequate quantity.

Our primary and only practical source of energy is the sun. The sunshine falling upon a square mile of land at sea-level in our latitude in the course of a year is equivalent on the average to 700,000 horse-power. To give us each the amount of energy we are now employing, one and a half horse-power, 60 square feet would be sufficient.

But no satisfactory solar engine has yet been discovered, so we are not able to make use of this abundant supply directly. Indirectly we can employ it in various ways. The heat of the sun causes currents in the air which we can use to propel sailboats and run windmills. Doubtless wind-power can and will be used more in the future for both purposes, but the winds are variable and insufficient. The same may be said of the waves and of the rise and fall of the tides caused by the attraction of the sun and moon. Something may be done with them, but we must not expect too much.

The power that the sun provides continuously by pumping up water from the sea and depositing it upon the mountains in the form of rain can be used by damming up the streams and interposing turbines. We should make use of such water-power as rapidly and completely as possible to save our fossil fuel, but there is not enough of it in all the world to replace the coal consumed and even in our favored land we could barely get enough power by harnessing all the falling streams to satisfy our present population, to say nothing of future needs.



DR. CHARLES D. WALCOTT

Secretary of the Smithsonian Institution, president of the National Academy of Sciences, formerly director of the U. S. Geological Survey, elected at the Boston meeting president of the American Association for the Advancement of Science.

Some day the world will have to stop drawing upon its carboniferous banks and live within its income. It will have to grow its fuel year by year as it grows its food. But it would be a great shock to civilization to have to shift back from coal and oil to the wood of two hundred years ago.

When we turn from the sun to the earth, we find here also an abundance of power but no way to get it. We are living on top of a furnace, but fortunately for us the lid is thick and non-conducting. It has been often suggested that a hole might be bored down through the crust of the earth into the heated interior a few miles below and through this water might be poured down to come up steam. But this remains an engineering dream.

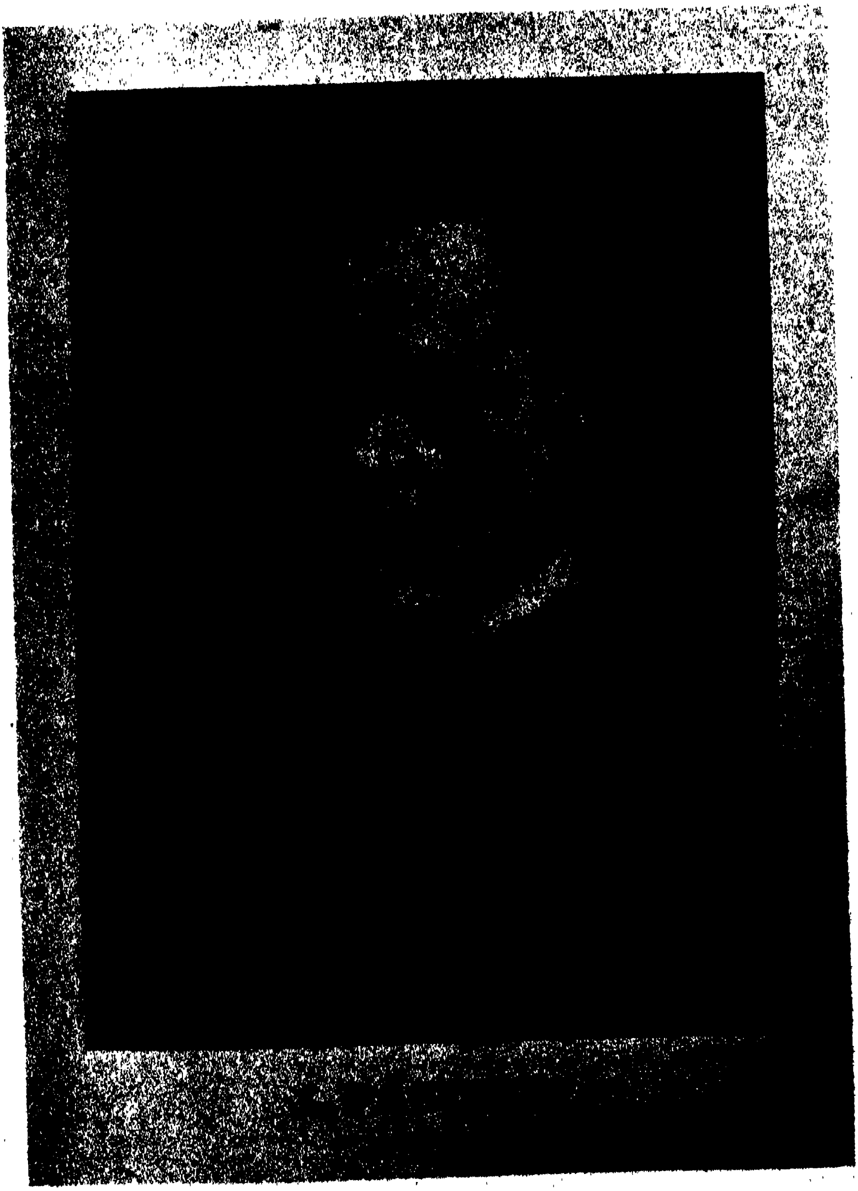
Last and most illusive of all is the internal energy of the atom, revealed to us in the heat that radium is continually giving off. We are using radium rays already to illuminate watch dials and scorch out cancer, but all the elements have similar stores of energy if we only knew how to release it. What it would mean if we should gain access to this exhaustless supply of potential wealth H. G. Wells has tried to tell in his romance, "The World Set Free," but even his brilliant imagination is baffled by its dazzling possibilities. But so far scientists have not been able to unlock the atomic energy except by the employment of greater energy from another source.

Such in brief is our present situation and future prospects. The lesson of it is, first, that we should curtail the waste of our coal and oil, a loss to our country of a billion dollars a year, and, second, that we should start systematic research to develop new means of obtaining power, such as a machine for converting the sunshine into electrical current.

ELECTRICITY FROM SPUTTER WORK

Power, more power, is the cry of the age. With a coal shortage upon us in midwinter and with a permanent petroleum famine impending, the eyes of the thoughtful are turned toward the development of new sources of heat and mechanical energy. There are two sources known that would satisfy all our wants if we could make efficient use of them. One is the heat of the sun and the other is the internal energy of the atom. The sun's heat we do use indirectly by the combustion of wood and coal. But the plant is a shockingly inefficient solar machine. No up-to-date factory would use such a wasteful machine, although we should not complain of it so long as we can not beat it. But some day we may be able to transform heat directly to electric current without going through the roundabout way of growing plant and steam engine and dynamo.

A new way of generating electricity directly from heat was pointed out by Dr. R. M. Holmes, of Cornell University, before the American Association for the Advancement of Science at the Boston meeting in Christmas week. His apparatus might be called "the sputter transformer," since it uses a film made by what physicists call "sputtering," that is, the driving off of extremely minute particles of a metal by electricity in a gas of low pressure and catching them on a glass plate. A film so made contains some atoms of gas entangled in the metal. Anyhow it acts like a different metal. Now it has long been known that when two wires of different metals are soldered together in a ring and one junction heated while the other is cooled an electric current will start up and flow around the circuit. When the two wires are of the same metal no current is produced. Now Dr.



DR. EMILE ROUX

Since 1878 associated with Pasteur in his work, since 1904 director of the Pasteur Institute in Paris.

Holmes finds that his sputtered film, when connected up with an ordinary piece of the same metal, will produce a current when the two junctions are heated unequally. To see if the absorbed gas was the cause of the difference in the sputtered metal, he tried the metal palladium which has the remarkable ability of absorbing a thousand times its own volume of hydrogen gas. The gas-filled palladium connected up with the ordinary gas-free palladium was found to work in the same way, that is, a current passed from the former to the latter at the cold junction.

Where did the current come from? According to modern theory an electrical current is a stream of loose electrons, that is, of atoms of negative electricity. All metals are supposed to contain such electrons wan- freely like the particles of air in a room. But different metals have different numbers of them in the same sized piece of metal, and when a metal densely filled with them is brought into contact with a metal wherein they are comparatively scarce, they pass over into the emptier room. If this junction is kept cold and the other junction is heated the current is continuous. Dr. Holmes suggests that in his gas-filled metals the gas molecules may have crowded the electrons into smaller space and so increased their pressure, or else that the extra electrons may come from the hydrogen atoms.

To avoid raising false hopes Dr. Holmes adds that "there seems to be no possibility of applying the method for the generation of electricity upon a commercial basis because of the smallness of the effects produced and because of certain losses which seem

CONFERRING OF THE NOBEL PRIZES AT STOCKHOLM

The directors of the Nobel Institute and winners of the Nobel prizes (each of which is of the value of $40,000). Those to whom prizes were awarded and who were able to go to Stockholm are in the front row. From left to right they are: Professor Niels Bohr, of Copenhagen, who received the prize in physics for 1922; Professor Francis William Aston, of Cambridge University, who received the prize in chemistry for 1922, and Professor Frederick Soddy, of Oxford University, who received the prize in chemistry for 1921. Professor Albert Einstein, who received the prize in physics, was unable to be present owing to the eclipse expedition to the South Pacific.

inevitable with any arrangement for this direct transformation of heat into electrical energy." So if the reader is approached by an agent with an agate-bearing tongue to take stock in a sputter engine he should investigate before investing. Still it is interesting to know of a new way of solving this vital problem, even if it does not seem of practical value. Here is a most enticing field of research for it offers both fame and fortune. An efficient transformer of the radiant energy of the sun into mechanical work would put a power plant in any vacant lot and make a desert as valuable as a coal field.

EARLY RISERS

THE youngest man to receive a Nobel award is Dr. Niels Bohr, of Copenhagen, who this month is awarded the prize for the greatest discovery in physics. He is only thirty-seven now and he was only twenty-eight when he startled the world by his bold conception of the atom as a sort of solar system in which the sun is represented by a nucleus of positive electricity and the planets by particles of negative electricity revolving around it with amazing speed. On this theory he was able to calculate just what shiftings in the orbits of these planetary electrons would give off light of the particular wave-length to make each line of the spectrum.

But it was a man even younger who in the same eventful year, 1913, made a still greater contribution to our knowledge of the interior of the atom. Henry Moseley, the Englishman, was only twenty-six when he found a way to analyze the elements by the reflection of X-rays from their atoms. This led him to "the most important generalization in the history of chemistry since Mendeléff's Periodic Law," the idea that the chemical properties of an element depend upon the number of free charges of positive electricity upon its nucleus. This shows us that there are ninety-two possible elements between hydrogen, the lightest, and uranium, the heaviest, and they are now all known but four.

Two years later young Moseley was killed at Gallipoli and the premature extinction of his brilliant brain was one of the greatest losses of the great war, a loss that no territorial gains can compensate, and it was, as we now know, a useless sacrifice, for Gallipoli has gone back to the Turks. "Some one had blundered."

In the history of science we often observe that epoch-making ideas have sprung from the brains of young men. Svante Arrhenius, the Swede, was only twenty-four when he devised the electrolytic theory of solution, the idea that salts are decomposed in water to positive and negative parts. Kekulé, the German, was twenty-eight when he hit upon the theory of types, which led him, at the age of thirty-six, to the symbol of the benzene ring. Berthelot, the Frenchman, was only twenty-four when he began his career in what he called "creative chemistry" by the synthesis of benzene compounds. William Crookes, the Englishman, was twenty-nine when he discovered thallium by the spectroscope, a new metal by a new method. Emil Fischer, the German, was twenty-three when he discovered the hydrazine reaction that led to the analysis and synthesis of the sugars. Perkin, the Englishman, was eighteen when he discovered the first anilinc dye, mauve. Pasteur, the Frenchman, was twenty when he became intrigued with the puzzle of the right and left-handed crystals of tartaric acid which six years later he solved by making the inactive racemic acid by combining the two forms.

Twenty years later the explanation of this phenomenon burst simultaneously in the brains of two young men, the Frenchman, Le Bel, and the Dutchman, Van't Hoff. The former

was twenty-seven and the latter was twenty-two. Van't Hoff was still a student when he published his eleven-page pamphlet on "The Structure of the Atoms in Space," and how he did get laughed at by his elders for his crazy notion.

Albert Einstein conceived the idea of his theory of relativity when he was eighteen and published it at twenty-six. He is, as we should expect, an advocate of shortening up the school period and making it more practical, so that the student can get at his life work earlier. This at least seems the best plan for brilliant minds like these and educators are coming to the conclusion that special facilities should be afforded such so they can advance as fast as they can without waiting on their slower schoolmates. To give one young man of this sort the peculiar training he needs will benefit the world more than the education of a whole collegeful of the ordinary caliber.

O. W. Holmes used to say of infant prodigies that those who get up so early in the morning are apt to be very conceited all the forenoon and very sleepy all the afternoon. But this does not seem to apply to the cases we have here considered.

SCIENTIFIC ITEMS

Dr. Charles D. Walcott, secretary of the Smithsonian Institution and president of the National Academy of Sciences, formerly director of the United States Geological Survey, has been elected president of the American Association for the Advancement of Science.

Dr. W. W. Campbell, director of the Lick Observatory, Mount Hamilton, California, on January 4 was unanimously named president of the University of California by the regents, succeeding Dr. Davis Prescott Barrows. Dr. Campbell remains director of the Lick Observatory. He will take office on July 1, when Dr. Barrows will become professor of political science.

Dr. Samuel Wesley Stratton, director since its establishment in 1901 of the Bureau of Standards, now president of the Massachusetts Institute of Technology, was the guest of honor at a farewell reception at the bureau on December 14.

Dr. Robert A. Millikan, of the California Institute of Technology, Pasadena, has been awarded the 1922 Edison medal of the American Institute of Electrical Engineers, for "meritorious experimental achievement in electrical science."

Dr. Hans Zinsser, since 1913 professor of bacteriology at Columbia University and bacteriologist of the Presbyterian Hospital, has been elected as professor of bacteriology and immunology in the Harvard Medical School.

The Rockefeller Foundation and the General Education Board have each given $1,250,000 to the College of Medicine of the State University of Iowa. The legislature will be asked to appropriate $2,500,000 at the rate of $450,000 a year for the building and equipment of hospitals and laboratories.

Princeton University has received a gift of $100,000 from Henry Lane Eno, research associate in psychology, and $25,000 from an unnamed alumnus, for the construction of a psychological laboratory.

THE SCIENTIFIC MONTHLY

MARCH, 1923

THE CENTENARY OF GREGOR MENDEL AND OF FRANCIS GALTON[1]

MENDEL AND HIS CONTEMPORARIES

By Professor E. M. EAST

BUSSEY INSTITUTION, HARVARD UNIVERSITY

IN law the *death duty* is a tax imposed on the transfer of property at the owner's death. It is a tribute which the legatee pays to the public in return for an acknowledgment of title to his inheritance. To-day we publicly pay a death duty for the intellectural legacy which we as biologists have received from Mendel and his contemporary fellow-workers. We meet to proclaim our indebtedness to the men who found the study of heredity buried in the depths of a hazy mysticism, and left it one of the most firmly established branches of quantitative biology. There is an element of affection apart from the sense of justice in making this acknowledgment. We know that nothing that we can say here will add to or detract from the merits of these men of the latter part of the nineteenth century, but we wish to say a few words of homage as a free-will offering to the excellence of past greatness.

I was quite proud of the above paragraph when it was first written. Having listened attentively to several political orators on Memorial Sunday, I felt that it had just the proper shade of artistic solemnity expected on such occasions. In fact, it seemed as if both custom and decency demanded a series of eulogies attuned to a motive resembling the Dead March from "Saul." But I am told that this apparently decorous procedure is a mere subterfuge which deceives no one who has been taught the rudiments of interpreting the subconscious. What we really do in a case like this, I learn, is to use it as an opportunity for releasing various over-

[1] Papers in honor of the centenaries of the birth of Gregor Mendel and of Francis Galton, presented at a meeting of the American Society of Naturalists held at Boston, on December 29, 1922.

compensations from the springs of our own vanity. These supposed tributes are defense reactions. Their true purpose is to show how much better is the scholarship of the present day—that is to say, our own scholarship—than any which went before. Our motto is *De mortuis nil nisi bonum,* but our memorial wreaths are twined with poison ivy. We are not far from following the intent of the epitaph of the gentleman of the frontier, without a single redeeming quality, without a single friend, whose fellow-townsmen marked his last resting place with the truthful inscription: "In memory of John Black the citizens of Crimson Gulch are happy to erect this monument."

One is doomed, therefore; if he escapes Scylla, he is certain to be wrecked on Charybdis. According to my informant, if one praises, his encomiums are accounted like those of him who expatiates on the superb tennis of the opponent he has just beaten; if he is critical, he lacks the good taste to conceal either his envy or his egotism. It is disturbing thus to be initiated into the secret sordidness of the human soul. I had intended to utilize this auspicious occasion to inquire into the *reasons* for Gregor Mendel's successful masonry in laying a solid foundation for twentieth-century genetics. It appeared to be a worthy academic question which might have a modicum of importance in determining future trends in biology. I could have entered the affair stimulated by the valor of ignorance, like the Honorable William Jennings Bryan, and have said whatever seemed fitting; now I suppose I ought to be as circumspect as a speaker at a birth-control meeting with Anthony Comstock on the front seat.

Fortunately one need neither admit nor deny the contentions of these psycho-analysts. Let the actual personal motives for our actions be what they may, there is an obvious reason both for praising and for criticizing in this particular memorial celebration, which ought to be satisfactory to all concerned. Whether we belong to the aristocracy or the proletariat of science, whether our day be the nineteenth or the twentieth century, let us do one another the honor of believing that each can be counted among those who seek the plain unqualified truth. If, therefore, we do not judge those of the past as carefully as those of the present, we do both an injustice; in plain language, we are insincere ourselves, and we assume that our predecessors were such false scientists as to prefer hollow eulogies which lead nowhere to critical discussions which might aid in banishing error and fallacy.

When one speaks of co-mendelian genetic biology, he must include the sixty years previous to the beginning of the twentieth century if he is to obtain any enlightenment on the subject of Mendel's triumph. During this period there were three types of

work in progress which contributed directly to the establishment of genetics—experimental breeding, morphology and demographic mathematics. If one should undertake to enumerate the investigations which contributed their mites indirectly, he would be compelled to list every advance in knowledge made, for science seems to be like the colonial protozoan, faring best when cultivating interdependence.

The experimental breeding of the time was plant breeding. Animal breeding, of course, was much older; but as a method by which to discover new facts in pure science, it remained in the same stage of moribund quiescence from the time of the Babylonians, until rejuvenated by the quantities of interstitial tissue inserted by the zoologists of the present day. Plant breeding in England, France and Germany, on the other hand, had established several very interesting truths, such as the similarity of reciprocal crosses, the high variability of hybrids of the second generation when compared with that of the first, the dominance of characters and the reappearance of characters after being lost in the melting pot of the first hybrid generation. The names of the workers who made these discoveries are familiar. Among them are Gärtner, Godron, Lecoq, Herbert, Naudin, Vilmorin, Klotzsch, Carrière, Wichura, Hildebrand, Jordan, Haeckel, Henslow, Focke and Darwin; but with the exception of Darwin, I doubt whether any one of us could say who they were, what was their training, how they worked or what they added to the world's knowledge. Presumably they were all worthy men, who, outside of the ignominy of being botanists, had nothing to their discredit; yet if they can not be termed the unknown soldiers, at least they are the unremembered soldiers, of genetics. Why? Is the growth of science essentially so slow and so continuous that our attention is attracted only by a sudden showy change, which, like the bursting of a chrysalis, is merely the sequel to something of more importance which went before? Or, does a particular piece of work, such as that of Gregor Mendel—or rather Johann Mendel, to give him his correct name, have a value *per se* which transcends the others completely? Probably both questions should have affirmative answers. I think that all too often the unknown private deserves a considerable part of the credit usually given to the colonels and generals and chiefs of staff; but in this particular case, there is evidence of a real value to Mendel's contribution which puts it in a separate class. In this array of names are competent men, who worked hard and intelligently, who made discovery after discovery; but it would have made little difference to twentieth-century genetics if they had been tailors or bricklayers instead of plant-hybridizers. I think we need not lack in respect for every one of them if we say

frankly that they did not deliver the same class of goods. Mendel was familiar with the results of the earlier researches through Gärtner's huge compendium of investigations on plant hybrids, and he had read both Nägeli's paper on hybridization and Wichura's account of inheritance in the willows which appeared in the same year as his own work. There is no evidence of his knowledge of the investigations of the French horticulturists of the period, Vilmorin, Carrière, Godron and Naudin; but had he known them thoroughly, he would have been under no necessity of modifying the statement in the preface of his paper, wherein is shown more clearly perhaps than in any other place his grasp of the essential requirements of science. He says:

> Those who survey the work done in this department will arrive at the conviction that among all the numerous experiments made, not one has been carried out to such an extent and in such a way as to make it possible to determine the number of different forms under which the offspring of the hybrids appear, or to arrange these forms with certainty according to their separate generations, or definitely to ascertain their statistical relations.

Morphology, or rather the part of morphology concerned with cell development and in particular with germ-cell development, was not in the same case as experimental breeding. The cell theory had not only one great paper in the latter half of the nineteenth century—it had fifty, each of which gave real insight into the subject. In fact, by 1895, knowledge of the cell was almost as far advanced as it is to-day. It is doubtful whether even the facts which flooded from the pedigree-culture work between 1902 and 1912 were either so numerous or so valuable to general biological progress as were those discovered by cytologists between 1877 and 1887. The mere mention of names like Van Beneden, Carnoy, Fleming, Oskar Hertwig, Strasburger and Boveri, is sufficient to call to mind what master craftsman flourished in those days. No man could take *their* papers and point out that they had failed to avail themselves of the possibilities of the method of attack used. In so far as the method had possibilities, they were turned to account.

Of demographic mathematics, the third type of work useful to genetics directly, less can be said. On the purely mathematical side, the theory of probabilities, which, during the last two decades has been found to be of such great value in solving biological problems, had long been developed far beyond the immediate needs of biologists or their ability to apply it. Such application as it had throughout this period was largely as a means of grinding out various conclusions from human vital statistics; and the results were used by economists and by life insurance actuaries rather than by biologists. I doubt whether any attempt had been made to

apply the method to the solution of fundamental biological problems before the efforts of Mendel and Galton, although Quételet did use it in certain special anthropological researches.

This being the state of affairs at the time, can one by its consideration draw any helpful conclusions as to the degree of success or failure attending the efforts of the various workers involved? Such an attempt, I believe, is not altogether hopeless or wholly worthless. It is the type of introspection which every investigator ought to turn to now and then for the good of his own researches.

Let us assume the present stage of genetic thought to have been reached by a single extended and inclusive investigation, and that the technical requirements of this investigation can be determined by the simple biblical rule of judging the tree by its fruits. Having found these requirements, we can apply them as a yardstick to the actual investigations of the past and present. Without wishing to be dogmatic in the matter, I find them to be four in number. This is on the assumption that there will be no disagreement from the conclusion that science advances most rapidly by the use of the inductive method. They are: (1) the development of worthy laboratory methods, (2) the control of extraneous variables, (3) the determination of quantitative relations between the phenomena studied, and (4) the translation of the results into useful terms. The first three requirements are self-explanatory. By the fourth, I mean to say that science must have adequate shorthand formulæ by which extensive data can be expressed concisely, and that these formulæ must in turn be easily transformed into the everyday language of perception. Mendel's own system is a good illustration. Perhaps, like Archimedes, one also needs a fulcrum on which to rest his lever. It seems to me that many a piece of investigation fails to achieve the result which might well have been expected from its general conception and execution, because it begins in the middle of a complex problem and therefore has not the proper background of knowledge to carry it through. It tries to solve the cryptogram by taking a small sample from well toward the end. It usually works out much better to begin at the beginning, or at least where the other fellow left off.

Nothing novel is presented in this particular segregation of science essentials, and probably it is not so good a division as others could devise, but I believe that by keeping even this makeshift in mind, one can see rather clearly where the various contributions under discussion belong in the general scheme of things. It also gives one the opportunity of making a fair guess as to why Mendel's paper, which was in its way a model in form, remained with uncut pages for 35 years. He himself was fond of cheering his spirits by exclaiming "Meine Zeit wird schon kommen," but unfortunately it did not come until 16 years after his death.

Let us first endeavor to visualize the trend of thought during this period. There is first the host of hybridizers. Mendel took care of them in the sentence quoted. Without a proper background of facts, they had tried to solve these genetic problems having the greatest complexity. They had gone in for generic crosses by preference, and for species crosses by compulsion. Apparently it never entered their minds to make a cross between two nearly related varieties in order to simplify the complexity of the problem. They had the simple technique necessary for the particular mode of attack used; but they made no attempt either to eliminate controllable variables, to determine precisely the relation between the facts observed, or to reduce their discoveries to a system useful for predicting the consequences of like causes.

Turn now to the work of the cytologists. Naturally, in 1865, what we now accept as the fundamental facts were practically unknown. Only 15 years before botanists had been staging a battle royal on the subject of whether Schleiden's erroneous ideas regarding fertilization were true. The literature on the female gametophyte begins with Hofmeister in 1858. Real knowledge of the male gametophyte dates from Strasburger's paper on cell-formation and cell-division in 1877. The actual cells concerned in the fertilization of the higher plants were not described clearly until 1884. And the zoologists were no more clairvoyant than the botanists. Virchow did not develop the theory of cell continuity until 1858, and his papers, as is usual with new ideas, provoked attempts at scientific sabotage for a decade after that time. Fertilization of the egg by one spermatozoon awaited the demonstration made by Oskar Hertwig in 1875. The identification of the cell nucleus as the most important vehicle of inheritance, though suggested by Haeckel in 1866, was not made until it was emphasized to the world by the independent investigations of Strasburger, Hertwig, Kölliker and Weismann in 1884; and the reduction division of the chromosomes was not shown clearly until the appearance of Boveri's work on Ascaris in 1887. The general constancy of chromosome number, their individuality in size and shape, and the details of their behavior during maturation and fertilization did not come until well within the limits of the present generation.

But one must not be blinded by this course of events. Mendel's paper shows a clear grasp of the gross facts of fertilization, and those gross facts were sufficient for his needs. Furthermore, though, the cytological details which would have made it easy for others to grasp the full significance of the paper were not available until the second decade after publication, it must be remembered that recognition of his work did not come until 15 years after these

details were common knowledge. For these reasons I can not believe that it is correct to account for the peculiar neglect of Mendel's work by assuming it to be ahead of the biological *knowledge* of the time.

Let us look a little closer at the problem. Cytology has been said to be the statics, and controlled breeding the dynamics, of genetics. Perhaps there is enough truth in this analogy to show a slight difference in point of view, but even this is doubtful: they are both statical in nature, and differ most in the limitations imposed by the mode of attack. For example, if one were to take all of the facts discovered by pedigree culture work, he could infer a certain organization and mechanics of operation in the germ-cells; if, on the other hand, one were to correlate properly all the discoveries of cytology, he could draw rather accurate conclusions regarding the actual transmission of characters. Genetics could not have developed as it has without both points of view, however, for *a priori* possibilities, unless tested, have no essential value. But granting this to be the truth, even the most ardent cytologist will admit that from the broad point of view of general genetics, his calling has its defects. It has a beautiful technique; but the very fact that the laboratory methods are so refined makes it difficult to eliminate the obscuring influence of extraneous variables by the very commonplace contrivance of investigating large quantities of material under controlled conditions. Again, it is practically impossible, due to the nature of the method, to investigate material in such a way as to obtain an adequate statistical representation of the facts which will permit verifiable predictions to be made. One does not decry cytology in making this statement. Cytology deserves the highest respect. But it is necessary to point out the inherent difficulties under which the cytologist works, difficulties which make his accomplishments so much more to be acclaimed. He was in much the same predicament which one might imagine would be the plight of a group of scholarly Martians who found a stranded aeroplane out of gasoline. Using the best method under the circumstances—the cytological method—they would dissect the strange visitor carefully, and make the most minutely accurate drawings of the various parts. They would then speculate on the use of each part, and finally form a hypothesis on the value and use of the apparition as a whole. This procedure would be perfectly proper. Without it, they would probably be in a quandary to know what to do with the can of gasoline dropped overboard by the unfortunate birdman and finally found by a young Martian piscatorial expert at the bottom of a canal ten miles away. With it, the gasoline would be poured in the tank, and the hypothesis

tested forthwith. Now my belief is that Mendel found the can of gasoline and by his own method of reasoning knew what to do with it. But after stealing in at night and making the apparatus run, his fellow-countrymen were not able to understand his account of the machine, because the method of dealing with it was so foreign to their own experience.

I am speaking absolutely seriously. It will not do to attribute the plight of Mendel's researches to the limited circulation of the Brünn journal, for it was received by all the various universities of Germany and by many foreign libraries. It was due to a different cause, the inability of the biological mind to adapt itself quickly to an experience it had not had before. Mendel was not really a biologist though he investigated the heredity of both plants and animals—you will remember that he worked with bees as well as peas, though the records of his experiments with the honey-makers have never been found. Biology was one of his numerous avocations, like playing chess, organizing fire brigades, running banks and fighting government taxes. He was really a physicist, and brought to one of the great problems of biology the attitude of mind and the quantitative method of attack which had been in use for some time by physicists and by astronomers, and which was just coming to be used more widely by chemists. It was an unknown language to biology, though it fulfilled the essential requirements of scientific research better than anything which had gone before; and it came to biology at a time when those who were endeavoring to investigate inheritance by means of hybridization were not prepared for their task, and thirty years before the results of the slow-going cytological method of attack had progressed so far as to permit the formulation of a well-rounded hypothesis near enough to the truth to make it possible to outline the points to be verified and to make recognizable a plan of verification. Great as was the advance in cytological genetics during the latter half of the nineteenth century one can not imagine an appreciation of the Mendelian type of work by any of the investigators. Their minds were too carefully focussed on the individual fact. Either Darwin or Galton would have seen the truth clearly; but then Darwin and Galton were amateurs who were not trammeled by professional connection with the guild of biologists.

One finds additional reasons for accepting the point of view that it was the *method* which made Mendel's paper great, and the *novelty* of the method which made it unappreciated, if he studies carefully the generalized hypotheses on the subject of heredity during the nineteenth century. Really one does not need further demonstration if he has followed genetics from the time it passed out of the larval stage in 1900, and has seen how many of us as-

sume we are exhibiting a fine degree of super-scientific criticism instead of mere stupidity when we adopt the agnostic attitude toward novel genetic methods and newly discovered facts. But the pernicious influence of abstract theories on the mind, the seductive way in which such theories lead away from reality, is worthy of a word on its own account.

Paucity of facts did not prevent the author of yesterday from putting forth theories of heredity by the score. One has only to examine some of the huge tomes on heredity of 30 or 40 years ago—Nägeli's "Abstammungslehre" is a good instance—to realize that lack of knowledge was even an aid to the publishing business. Nägeli was able to write whole chapters on certain subjects manifestly because he had absolutely no information on them.

Each and all, these theories were as one in using mechanical interpretations which postulated active ultra-microscopic living units endowed by their creators with various qualities. No doubt this was just and proper. Such concepts have been found useful in various branches of science, and have been retained in the current theories of heredity. I only wish to point out that many of the hypotheses, described in such fanciful detail, have been hindrances rather than helps. If each of us were asked privately to state the object of scientific hypotheses, we should probably say, "to help formulate tests by which various assumptions can be justified or refuted." But publicly, in the class-room, and in the journal, we are very likely to become enamored of a well-presented hypothesis which does not stimulate research a whit, just because we are beguiled by its plausibility. Certainly a great many of the points discussed at great length by these early geneticists do not fit any better into a scientific discussion than would Cotton Mather's disquisition on the number of angels who could deploy on the point of a pin.

Recall Darwin's provisional hypothesis of pangenesis, as he termed it, proposed in 1868. His units were the gemmules, which were being given off constantly by every cell, including the germ-cells. That was virtually all there was to it, though it was propounded as a theory of heredity. In reality it was a prop, and a very weak one, to the theory of evolution. Darwin postulated this brisk inter-cellular trade in gemmules in order to show the literal-souled biologist how acquired characters might be transmitted. On the assumption that somatic modifications are not inherited, it was unnecessary. With the latter view, the cells might just as well have been insulated from each other as thoroughly as the wires in a telephone cable. Though it be sacrilege to say it, this was not the type of production to be expected from the author of the "Origin of Species." Apparently it stimulated but one ex-

periment, Galton's blood transfusion experiment, which we now know could have told him nothing one way or the other. It acted rather like Aaron's rod, with ink gushing out in place of water, and this effect was not for the good of science.

The most notable among the various modifications of this type of theory was that of DeVries, published in 1889. Here the corpuscles, which he called the pangens, represented potential elementary body characters rather than cell qualities, and the universe of their activity was the cell rather than the body. DeVries's theory, perhaps, was some small philosophical advance over that of Darwin, but neither was a real working hypothesis in which the possible mode of hereditary transmission was outlined in such a manner that the biological student was led to make experimental tests of the postulates involved. No doubt general evolutionary thought was somewhat clarified by their introduction into the literature of the day, but they stimulated words rather than work.

Nägeli's "Abstammungslehre," which appeared in 1884, has been credited with being the first theory of heredity endowed with qualities calculated to induce research. But was it such a theory? Nägeli proposed to distinguish two kinds of protoplasm built up of physiological units, the micellæ; the one was wholly nutritive in function and required no special architecture; the other, the idioplasm, was a structure of elaborate constitution built up from micellæ representing the potential characters of the organism. I can find nothing more in Nägeli's work, and it took him 822 pages to say this. Here was a man to whom Mendel had written in detail about his work during the years between 1866 and 1873, a man who had contributed notable papers to botany on subjects ranging from the form of the starch grain to hybridization, a man who discoursed at such length on chemistry and physics that one might suppose him to have had the greatest sympathy for the highest type of useful quantitative work; but he devotes absolutely no time or energy to discussing the one paper which might have shown him a way out of the wilderness in which he found himself. Was this science? I do not believe it was. It may have been only the garrulity of senility, it may have been philosophy, but it certainly was not science. There is no evidence whatever that it stimulated a single investigation or was the source of a single discovery. But Nägeli was no worse than the other theorists of his time. The three hypotheses mentioned are fair samples of some twenty or thirty which were proclaimed to the world during the last half of the nineteenth century. They have been cited only because they show, as nothing less concrete will show, where the unreal leads.

The obverse of the medal can be illustrated by Weismann's presentation of the subject.

In Weismann's theory, the idioplasm, or germplasm, was identified with the chromatin of the nucleus. The ultimate living unit, the biophore, was a kind of biological atom active in building up organic characters. They grouped themselves together into determinates which controlled the specialization of cells. The various determinants of an organism made up the ids contributed by past generations. The ids might be one or many; and where more than one might differ slightly among themselves, thus providing for variation within a species. The ids formed the chromosomes or idants by arrangement in a linear series.

These postulates seem simple enough and not unlike those of earlier theories, but the way Weismann reasoned in endowing his corpuscles with qualities was a distinct advance. It was made possible by his thorough knowledge of embryology in which he had previously made notable contributions.

Denying the inheritance of acquired characters, and doing much toward demolishing the fallacious logic put forth as proof at that time by adherents in the belief, Weismann outlined a very stimulating conception of heredity on this basis. The immortal germplasm was assumed to be set apart at a very early cell division and passed along unchanged to the next generation, except as the activities of the living units produced occasional changes in its constitution. A provision for accurate equational division of the chromosomes and their reduction in number at the maturation of the germ cells was thus demanded, predicted and afterward realized—though not precisely in the way he supposed—by discoveries in the field of cytology.

Weismann further accounted in part for evolution by a selective struggle between the determinants of the germ cells, and for individual development by a qualitative distribution of the determinants of those cells set apart to build up the bodies which were to act as hostelries for the immortal germplasm.

No matter what views one holds as to the precise amount of truth contained in Weismann's generalization, it is obvious that it is very different from the others mentioned. Many geneticists believe the modern theory to be the outgrowth of Weismann's ideas. Wilson says he brought "the cell theory and the evolution theory into organic connection." Morgan credits him with the basis of the present attempt to interpret heredity in terms of the cell, in that he suggested three of the principles used in this interpretation. Be this as it may, there is no doubt but that Weismann was the first to utilize all the facts at his command, and to utilize them very ingeniously, in building up a theory of heredity, which, whether true or not, had numerous points that could be tested by experiment. In my opinion, it is by this criterion of ultimate usefulness and not

by any analysis of its content of reality, that its greatness should be measured.

This presentation of nineteenth century genetic work necessarily having been very sketchy, no apology need be made for summing up the points of the thesis involved. Mendel initiated a method whereby the elementary quantitative relationship between hereditary phenomena could be tested and retested, and expressed his results in an algebraic notation of greatest usefulness. He thus supplied to genetics an essential methodological requirement which it previously had lacked. The significance of his offering is now apparent; but the history of both genetic research and genetic theory show that biology was not ready for such a profound change at the time. The investigators were satisfied with defective methods because they were yielding important results, and were capable of continuing to yield important results up to a certain point; and those who theorized, not realizing the defects of the current methods of research, wandered about aimlessly in the universe of the unreal. Obviously, if one is to find a clear exposition of genetic thought anywhere, it should be in the generalized theories of heredity. Taking them in the order of their issue, there ought to be a history of the development of this thought. And it seems to me that they show clearly that previous to 1890, biology was unprepared for the quantitative method of physics and chemistry; yet this method was a prerequisite for continued progress. Let us put the matter in another way, for the sake of emphasis. The older methods of genetic research were inadequate, the breeding work because the workers did not know how to use their tools, and the cytological work because the workers lacked the proper tools. Nevertheless, they made progress. They built slowly but firmly an edifice that future generations may well admire, much as the laborers of ancient Egypt built the pyramids. Finally, there arrived the point when a man like Weismann could piece together a well-rounded theory of heredity based almost wholly on this cytological evidence, which was testable by experiment. But for the tests required a new method was necessary, and this method was not forthcoming until the discovery of Mendel's long-forgotten paper. From that time onward, genetics entered a new era.

Properly, this paper should come to an end at this point; but I can not stop without delaying a moment to pay a passing tribute to Francis Galton, even though I realize that Dr. Harris will do full justice to his memory. Galton, as mentioned before, was one of the few of Mendel's contemporaries who would have appreciated his work. He was a kindred soul to Mendel, a brilliant amateur, interested in everything; and but for a matter of mere chance, he probably would have reached the same goal. The matter of chance

was the study of ancestors instead of descendants. It seems a minor point, but it turned out to be important. Thus the Fates play with mankind. Galton was a leader of thought in England; he was no novice in biology; his capacity in mathematics was unquestionably great; and he turned instinctively to experiment. If only this single slender thread had not obstructed his efforts, one can well imagine how far he would have gone. But perhaps it is all for the best. Statistical theory needed Galton's guiding hand. It would not be the same to-day had it not received the quickening touch of his genius. Peace be unto his name!

THE BEARING OF MENDELISM ON THE ORIGIN OF SPECIES

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STUDENTS of genetics have often been challenged to state the bearing of their work on the old controversy about the origin of species. If the challenge has often been allowed to go unanswered, it is not because geneticists failed to have an inkling that their results might, in the end, have a significant bearing on this question, but rather because they recognized the need of first putting their house in order. The futility of attempting to arrive at any reliable conclusion concerning the origin of new types until something more was known about heredity had become only too manifest during the debates of the latter half of the last century. It required no subtlety on the part of geneticists to see that only those characters can take part in the process of evolution that are inherited. It seemed to follow that it would be better to find out what characters are inherited and how they are inherited before the controversy could be continued profitably.

Geneticists do not make any claim to have solved the problem of the "origin of species." I am afraid to "protest too much," for fear that you may conclude that we really do think so. We can (and we know that we can) furnish certain evidence—important evidence, we believe—that bears on the origin and mode of inheritance of new types. It is this evidence that I am going to consider to-day. How far these new types furnish the variations that make new species may depend on what we call "species." If, as some systematists frankly state, species are arbitrary collections of individuals assembled for the purposes of classification; or if, as other systematists admit, there are all kinds of species both in nature and in books, it would be absurd for us to pretend to be

able to say how such arbitrary groups have *arisen*. It is possible that some of them may not have arisen at all—they may have only been brought together by taxonomists.

I am not criticizing the taxonomists, but I am letting you know that I know that we are embarked for the next quarter of an hour on a hazardous undertaking.

I am not sure, moreover, how far students of taxonomy want our help. They suspect us a little, bearing gifts. I am not sure just what they could make of our conclusions if they accepted them. The systematist may be quite right in following his own methods of arranging the animals and plants living on the globe to-day; he may be quite content to allow the geneticists to make a different arrangement. Neither is quite decided at present whether or not to let the other alone. However, there should be no quarrel between us! On the contrary, I have never failed to find that we have innumerable points of contact. I am of the opinion that we can be of mutual assistance, and I sincerely hope the systematists present will agree in this pious wish.

The *modus vivendi* that I suggested a moment ago seems to me to have its points. Is it not possible that the kind of classification the taxonomist needs for purposes of identification may be very different from the classification that the evolutionist needs to indicate lines of descent or of relationship? Is it not possible that the geneticist may need still another classification to indicate how many genes certain types have in common and in how many they differ? Each of us might, if he wished, erect a species definition of his own, and each would be within his rights in forming such a definition. Whether it would be desirable for the evolutionist to use the word "species," that tradition has assigned to the systematist, is a question for the evolutionist to decide; but, as I have said, it is a perilous adventure for a geneticist to attempt to interpret the historical species in terms of genes. It may also be a work of supererogation.

Hence, whenever I refer to species, in what I am about to say, it is very probable that I shall sometimes use the word in all its vague implications—much in the same sense in which Darwin used it; but when sharply defined issues are at stake I shall try to remember to use other words.

Animals and Plants under Domestication

Darwin's largest single contribution to the origin of species grew out of his observations and experiments on "Animals and plants under domestication." Here also is the field in which modern genetics has reaped an abundant harvest. Taken broadly

the results have strengthened Darwin's thesis that by artificial selection man has brought about those adaptations to his needs, or to his fancy, that our domesticated products show. Granting that some of the variety shown by cultivated plants and domesticated animals has also been obtained by outcrossing with different wild races, there still remains a good deal that appears to have arisen by the selection of new mutant characters that have appeared under domestication. It is seldom possible to tell whether a variation was obtained by outcrossing, or by mutation; but, if, as I shall try to show, the heritable differences that distinguish wild types and races also represent mutant changes in the germ-material, then it makes practically little difference whether new characters arise in nature (and are later incrossed), or under domestication (and then inbred).

The evidence that all heritable variations may have had the same kind of origin rests on the following facts and argument: We have found that the mutant types that appear in our cultures follow Mendel's laws of inheritance; practically all the character differences of domesticated races also fall under these same laws; it can scarcely be questioned, therefore, that we are dealing in both cases with mutant characters.

There are also records of mutants appearing under nature that have been found to follow Mendel's laws. There are also cases in which wild varieties, differing from each other in distinct characters, have been shown, when crossed, to come under the same laws.

This accumulated evidence speaks strongly in favor of mutants as furnishing the basis for artificial selection, regardless as to whether the mutants have appeared under cultivation or in nature.

Darwin knew about mutants, calling them sports; and, as every one knows, he rejected sports as furnishing the kind of steps that the evolution of species seemed to call for; because, he said, such gross modifications of particular parts of the body as are seen in sports could rarely be adaptive. Only by small changes in a great many parts could arise those interrelations of parts necessary for survival.

To-day we agree with Darwin that such extreme variations as those he called sports would rarely, if ever, have contributed to the formation of new types in nature. But we also know that minute differences also arise as mutants, and that these are inherited in the same way as are the larger mutant changes. It is also now clear that these smaller mutant variations must be those small heritable variations that Darwin himself appealed to as furnishing the materials for organic evolution. In these respects we have made great advances in knowledge since Darwin wrote; and I

doubt if a single geneticist familiar with the evidence at first hand will hesitate to make this substitution. We have learned to distinguish between those individual differences due to the environment (that are not inherited) and those that arise as mutations (that are inherited). Superficially there is no way of telling one from the other, since they overlap and involve the same changes in the same characters. But by pedigree work the essential difference can be made evident, as Johannsen demonstrated in 1909.

What was not entirely clear, when Darwin wrote, has been set straight. This is one of the most notable advances in the study of variation since the publication of the "Origin of Species."

Multiple Effects of Single Changes in the Germinal-material

We have also discovered another most significant fact about those changes in the germinal material that produce mutant characters. It has been found that a single change in one gene often affects the animal or plant in more than one way; sometimes in many parts of the body. Even very different kinds of organs are often affected by the single change. Students of genetics have known for some time that the so-called unit character is a fiction—one that may have been excusable in the earlier stages of the work, but one no longer tenable or desirable. To-day we are familiar with many cases that show the multiple effects of a single change in the germ-material.

It is true that we still find it convenient to single out that effect of the gene that is sharpest, most easily observed and most convenient in the separation of Mendelian classes. We often visualize this particular effect as the single result of an alteration in the germ-material; but no practical geneticist forgets that as a rule many other effects are also produced by the same mutant change. DeVries laid emphasis on this point. He regarded each mutant change as one that affects the individual in every part—made a new elementary species out of it, he said. I think de Vries' view is much nearer to what we actually find, when mutants appear, than is the view that over-emphasizes unit-characters.

If, then, as I have just said, we pick out a superficial effect of the mutant change, as the symbol of that change, we do so because we can most easily follow its course in heredity. We ignore as a rule other subsidiary changes in the organism, such as those involving physiological processes; but the literature is full of incidental references to such subsidiary effects. Pearl's recent studies of the length of life of mutant races open up a new field of investigation in which the physiological by-effects of superficial mutant characters probably play an important rôle. It need not be argued, I suppose, that slight changes in the physiological effects

of a character of a species are those that most nearly affect its chances for survival. I think it would be rational to take for granted that changes of this sort have been the ones that have played the most important rôle in evolution. Now reverse the argument! If beneficial mutant changes, involving physiological changes, also often affect superficial parts, it is the latter, being visible, that might be chosen as the mark of the species. Here we may find an answer, I think, to the old riddle, that while natural selection is supposed to produce new species by the selection of variations essential to the life of the species, our definitions of species are based almost always on trivial, superficial characters that have, so far as known, no survival value.

In other words, the systematist has followed the same course as the geneticist. He has chosen superficial differences as the distinguishing marks of his species—he has not been concerned with the characters that have in reality created the species.

If, then, physiological changes have most often been the basis of natural selection, it follows that we may get into an inextricable tangle, if, taking the systematist's definition of species, we attempt to harmonize such a definition with physiological differences between species to which the taxonomic definition has only a secondary relation. I am inclined to think that a good deal of unnecessary worry can be traced to this source.

Losses of Characters and Absences in the Germinal Materials

Within the ranks of geneticists themselves doubts have sometimes been expressed as to whether *any*, even the smallest, of the mutational changes that we study are of such a kind that they could produce the advances in complexity that evolution is supposed to demand. I shall not try to avoid this issue by pointing out that evolution is also sometimes backward as we say, *i. e.*, towards simplification. It may be conceded at once that many, perhaps nearly all, of the mutant types, that appear in our cultures, show not only deficiencies and losses of characters, but even that most of them could not possibly have any significance for progressive evolution. These admissions do not exhaust the subject by a long shot.

Let us look a little deeper into the situation. No one doubts that each animal and plant is adjusted in a great number of ways to the complex environment in which it lives. We can imagine hundreds of changes in any animal, but it is difficult to suggest one that would certainly be an improvement, when all the many sides of its existence are taken into account. Is it not clear, then, that almost every random change must be a disadvantageous one? This is what we actually observe when a new modification of an old character takes place. But note! Among the multifarious possible

changes there *may be one* that is an improvement, in the sense that the new animal is better adapted to the old environment, or that it can better adjust itself to a slightly different one. This possibility suffices for natural selection.

In the limited range of our personal experience it is not to be expected that the mutations we find would be advantageous ones, but when we consider the vast number of individuals that make up a species, the supposed difficulty does not appear insuperable.

Bateson, who has emphasized the fact that most mutant changes are losses and deficiencies, draws the conclusion that loss in the character means loss also in the germ-material. If it were true, as he supposes, that loss of character is to be interpreted to mean that something has also dropped out of the germ-material, then I think we might begin to look elsewhere for the materials of evolution, for I can not follow Bateson in his suggestion that evolution may only mean a succession of losses. I believe the premises are wrong.[1] Again, when we look at this question of losses in character from the point of view of embryology, it is not in the least surprising that almost *any* kind of change in the germ-material would bring about defects in character. If each character is the end result of a long series of developmental (embryonic) stages, it follows that almost any alteration at the start will be expected to make less perfect the end result, for less perfect here means only something different. This I take it is what most often happens.

It also seems to me quite illogical to infer that because a change in the germ-material may bring about a defect in the developmental process, this change in the character is to be interpreted as a loss from the germ-material. Such a conclusion seems not only unnecessary, but, what is more important, it is in flat contradiction with the only critical evidence that we have bearing on this question. I mean the evidence from the order of appearance of the multiple allelomorphs of Drosophila.

Much also has been said concerning dominance and recessiveness of mutant characters in relation to the characters of the wild species. Bateson has emphasized the fact that most mutants behave as recessives to wild type characters. Hence he concludes that these

[1] In his Australian address in 1914 Bateson's purpose was to point out to what conclusion one is led on the assumption that mutations are losses and if mutants are assumed to furnish the materials for evolution. In his Toronto address in 1921, on the other hand, Bateson appears to argue that the distinctive differences between wild species are something added, and therefore not the kind of variation about which genetics concerns itself.

The argument advanced here in the text accepts neither alternative, but rests on the interpretation that a mutation need not represent a loss of germinal material, and that the differences between species are probably mutant differences.

mutants do not seem to be the stuff from which wild species are made. Now, in the first place, while the statement that nearly all mutants are recessives may hold in certain cases such as Drosophila, yet there are other groups in which the number of dominant mutant characters is much in evidence. But the distinction itself between dominant and recessive is by no means so general as implied. Mendel described only nine pairs of characters, choosing those in which dominance is complete. To-day, we look upon these as rather extreme cases, not as the typical ones. We meet with many cases in which dominance is imperfect. The hybrid is intermediate between the two parental types, especially when all the different modifications of the pair of genes in question are taken into accocnt. The same gene may, in fact, be dominant in one respect and recessive in another. When the hybrid is intermediate, it is often purely conventional which alternative is chosen as the dominant. The real point at issue—Mendel's great discovery—is that genes separate cleanly in the germ-cells, even when the hybrid is intermediate. It befogs our problem, I think, to insist that dominance means complete dominance. With this sharp distinction done away with, the difficulty loses much of its apparent point.

Infertility between Species and Sterility of the Species-Hybrid

One of the oldest questions concerning the origin of species by the summation of individual differences is this—how has the infertility, commonly observed when species are crossed, arisen? No incipient infertility, it is said, can be observed when different breeds of domesticated animals are crossed. Darwin had to face this question, and met it in the only possible way that it could be met at that time. He pointed out that there is in reality no such sharp distinction as implied. He showed in a large number of cases that well-recognized species do cross, and that sometimes they even produce fertile offspring.

Since Darwin's time a great deal of work has been done by embryologists that bears on this relation. Every embryologist is familiar with the fact that sea urchins belonging to different genera and families can be cross fertilized. The early stages of development of the hybrids are often normal. It is only when the conflicting processes that are induced by the inherited characters of the egg and sperm begin to crop up that difficulties set in. When we take into account the delicately balanced processes that each stage in embryonic development involves, it is not in the least surprising to find an incompatible situation when conflicting interests are brought together.

Then again, in the higher plants mechanical and physical dif-

ferences may often account for the failure of the foreign pollen tube to reach the egg. Similarly, in matings between two species of animals there may be incompatible structures or responses. When such matters as these are given sufficient weight it is not going too far to claim that we are not dealing here with a single fundamental difference, but rather with several different kinds of processes that give like results.

It is true that new mutant types are fertile (if fertile at all) with the type from which they arise, because the single difference that distinguishes one from the other is a compatible difference. If it were not, the new type would be lethal. When, however, two types have been separated for a sufficiently long time, differences may be supposed to arise in one, or in both, that are incompatible in fertilization or in development. This seems to me to cover the case from a theoretical point of view.

Even the infertility often observed between the pollen and the ovules of the same plant is now in a fair way of being explained. The recent work of Correns, of East and of Compton has shown that such kinds of infertility depend on the presence of one, or at most a few, genetic differences. In such cases the failure to fertilize appears to rest on differences in the somatic tissue and not on incompatibility of sperm and egg or on difficulties in embryonic development.

That infertility may arise as a consequence of genetic differences has been shown by the recent work of Jones on corn and tomatoes. When pollen from one race was placed in competition with pollen of other races that differed only in minor features it was found that the plant's own pollen was the more efficient, *i. e.*, it fertilized proportionately more ovules. The result may fairly be interpreted as a case of *incipient* infertility in outcrosses. We do not know how frequently such a relation exists, because the problem has been very little studied with critical standards. The essential conditions for such work are seldom realized. On the whole, then, is it not a little remarkable to find in the one case where the problem has been adequately examined that the outcome has been positive?

Bateson has recently laid much emphasis on the *sterility of the hybrids* themselves in species-crosses as compared with the absence of such sterility when mutant races are crossed. In the latter case not only is there no incipient sterility in the F_1 offspring, but on the contrary the F_1 heterozygotes may, and often do, produce more offspring than do individuals of either parent race.

Bateson has laid a great deal of emphasis on the importance of this question for modern genetics. His studied wording of the requirements that would be necessary to demonstrate that inter-

racial sterility had arisen in connection with mutation is worth careful consideration: "The production of an indubitably sterile hybrid from completely fertile parents, which have arisen under critical observation from a common origin"—this "is the event for which we wait."

Bateson has made the conditions of demonstration extremely difficult. He postulates that "the event for which we wait" is one that must suddenly occur—as a mutation perhaps? If so, and if as seems to be probable in the case of other mutations, the expected change should occur in only one gene, it would by definition make sterile the animal that received this gene, and hence defeat any effort to prove its fertility. There are possible ways of escaping this dilemma, but these would detract from the generality of such origin of sterility.

Suppose, in order to avoid the contradiction in terms just referred to, we ignore the probability that mutations take place in one gene at a time, and suppose that a single individual of the new type called for has appeared as a duplex mutant. The chances are very great that it would be lost before its value was appreciated for the simple reason that it would have to be crossed to the original from which it arose in order to get any offspring at all. It is with this type that it is by hypothesis expected to give sterile offspring. Only when several individuals of the new imaginary type arose at once, or as a bud sport, could a race be produced with which to properly test the question of sterility of mutant hybrids according to definition. These and other considerations raise the question as to whether the sterility of species hybrids may be of such a nature that we are justified in insisting that they must arise under the conditions that Bateson postulates as essential. There is at any rate another side to the question which may throw some light on the situation from an entirely different angle. It is now well known that in those stages in the development of the germ-cells, that are concerned with the conjugation of the chromosomes, irregularities occur in the distribution of the chromosomes in species hybrids. As a consequence many or even all of the germ-cells are abnormal. Hence arises the sterility observed in such hybrids. In many cases these irregularities seem to be connected with differences in the parental numbers of chromosomes. Such a situation would not be expected to arise when mutation in a single gene has made one parent different from the other, but might be expected, if, due to doubling of the chromosomes of one of the parental gametes, there is produced a triploid individual. In fact, a disturbance, similar to that in species hybrids, has been described in some at least of the mutational triploids that have been examined. It would, however, be a mistake, I think, to assume that

the sterility of all species hybrids is due to differences in the parental chromosome numbers, although this may be the expectation when the numbers are different. There are other cases where the parental chromosomes are the same in number and the species hybrid is sterile; hence, there may be still other kinds of differences that make conjugation of the chromosomes difficult or impossible. One of the events for which I wait is the demonstration of such differences that interfere with the conjugation of the chromosomes and tend in consequence to produce sterility.

Recurrent and Parallel Mutants

Finally, the demonstration that the same mutant types recur over and over again has opened up new points of view with interesting consequences. It has long been known, in a general way, that the same kind of mutants reappear *in the same species*. We are now beginning to get evidence from pedigree cultures that the same types may occur *in different species*. At present there are only two ways in which we can be sure that the latter are due to the same kind of change in each species. One way to prove this is by crossing the two mutants. If both mutant characteristics are recessive, and give the recessive when crossed, the proof is established that they are identical mutants. Such a case has arisen between the two species of Drosophila simulans and melanogaster. Sturtevant has shown that there are thirteen mutants that are the same in both species.

The other way of showing that two mutants arising in different species are identical (isomorphs) is to find their linkage relations with respect to other mutants that also appear to be identical in the two species. This involves the possession of several such types in both species, as well as a fairly complete knowledge of linkage groups in both. It may take several years before enough material can be brought together for a safe conclusion, but the outlook is promising.

If, then, it can be established beyond dispute that similarity or even identity of the same character in different species is not always to be interpreted to mean that both have arisen from a common ancestor, the whole argument from comparative anatomy built upon the descent theory seems to tumble in ruins. This, however, is only a first impression; for, even if it be true that some of the resemblances between species may be due to identical mutational changes in the same gene, there remains the vast array of other characters that the two species still retain in common. These furnish the hint that the evolutionist needs to make probable his theory.

Should it turn out to be true that a large number of similarities

in species are due to similar mutations in the same gene, then, in future, the student of genetics will be more interested in detecting these identities than in taking account of the genes that have not yet produced new mutants. The evolutionist will be concerned with the genes that still remain unchanged because these will indicate a common ancestry. But, I think, he will be at his wit's ends to exclude from his lists those similarities that are due to identical mutational changes. Lest you infer that I am letting this idea run away with me, I should like to add that we are also only too familiar with cases where mutations, in quite different genes, produce effects that are so much alike that it takes a microscope to tell them apart—and even this may not suffice. Sometimes we even have to appeal to statistics to help us out.

Nevertheless, the discovery that the same mutation happens over and over again, not only within the same species but in different species, is, I think, one of the most interesting discoveries in recent genetic work. It means that certain kinds of changes in the germ material are more likely to occur than are others. If we adopt the Galton metaphor of the equilibrium polygon, these changes might be interpreted to be the more stable conditions of the genes. Or, if we prefer to think of the change in the gene as a chemical event we can form a somewhat different picture to ourselves as to what happens. Whatsoever way we prefer to symbolize the recurrence of the same event in the same gene the significant feature remains—the appearance of new variations in the hereditary material is something less a random process than we had hitherto supposed.

GALTON AND MENDEL: THEIR CONTRIBUTION TO GENETICS AND THEIR INFLUENCE ON BIOLOGY

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I

FRANCIS GALTON and Gregor Mendel have much more in common than the mere incident of the identity of the years of their birth. Both men worked in advance of the science of their own generation. Both have influenced in a profound and far-reaching manner the science of subsequent generations.

The fact that they have these common characteristics must not lead us too hastily to the conclusion that there is a detailed parallelism in their lives. Neither can the linking of the two names on the

same anniversary program be accepted as evidence that they are equal in intrinsic greatness or in their influence on science. It merely invites us to take stock of the work that the two men did and the movements that they set under way, with a view to deciding—if as individuals we choose to do so—which has contributed the most to the century which has passed and which has most to offer in inspiration and guidance for the future.

To this task we must turn in an effort to do the fullest justice to both men, but with that scientific candor which should characterize our attack on any problem.

II

Here lies our greatest difficulty. Scientific men are after all very human creatures. They fish in the same pools, worship at the same shrines, and sometimes have that almost pardonable human weakness of projecting haloes about a selected few of the human figures in the development of their science which are sufficiently distant in time and obscure in actual personality. In science we have no formally canonized saints. Nevertheless, we must not forget that we are to-day comparing two quite different entities—we are contrasting Sir Francis with Saint Gregor.

Here we reach our first point of contrast between Mendel and Galton. Mendel must be viewed through the halo which unconsciously but none the less definitely has been projected about him since the simultaneous rediscovery of the principles announced in his one noteworthy contribution raised him from almost total obscurity to fame. Galton's life is an open record.[1]

Mendel's life has been so often and so minutely portrayed in all ascertainable details that it will be impossible to add anything to what is already familiar. Galton's life was so rich and varied that it will be impossible to do more in the few minutes granted to me than to give a few illustrations of his achievements.[2] I shall attempt merely to balance the two personalities against each other, leaving the decision as to the relative importance of their work

[1] So detailed is the available information that a well-known psychologist has attempted to determine "the intelligence quotient of Francis Galton in childhood." See L. M. Terman, *Amer. Jour. Psychol.*, 28, 209-215, 1917.

[2] The present paper is in no sense an attempt at an abridged biography of Galton. I hope that it may stimulate the reader to read Galton's charming "Memories of My Life," which will be as fascinating to the general reader as to the professional biologist, and Karl Pearson's masterly biography, "Life, Letters and Labors of Francis Galton," which must remain for all time not merely the source of authoritative information concerning Francis Galton, but one of the most notable biographies of this century. It is much to be hoped that the near future will see the completion of this comprehensive work, long delayed by war activities.

and the relative significance of their influence on science to the jury here assembled.

III

A perusal of the mere facts of the lives of Galton and Mendel at once raises, but unfortunately fails satisfactorily to answer one of the questions in which Galton had a sustained interest—that of the relative importance of nature and nurture in determining the characteristics of the individual. Galton came of stock of long proved intellectual power. Mendel's more distant ancestry is hidden in obscurity, and there is no evidence of great intellectual ability in the parental generation. Galton's family could and did provide for him as a boy the best that the times afforded in intellectual discipline and inspiration. The beginnings of an education were for Mendel a rare opportunity and bought at a sacrifice to his family. Galton saw the world broadly, through his own eyes and through those of his friends—eminent in exploration, in science and in public life. Mendel's outlook was always limited by the walls of a narrow geographical cloister.

Yet both men have made great contributions to scientific advancement.

If for a moment I may be permitted to show partiality, and to venture at interpretation as well as presentation of facts, I must confess that it seems to me that as an individual Mendel deserves the greater credit for his achievement. Nurture fed all that was best in Galton's rich natural inheritance. Intellectual nurture was not lavished on Mendel. There may have been at one time real danger that Galton's abilities would be sterilized by luxury. There was grave danger that Mendel's abilities would never be of significance in scientific progress because of lack of opportunity.

Fortunately neither of these misfortunes was realized. In 1847 Mendel was ordained a priest, and in 1849 he was sent at the expense of his cloister to the University of Vienna, where he remained until 1853. It was in the midst of this period, in 1849, that Galton suddenly ended "the fallow years" of his life, ceased sowing his wild oats, and turned again to the scientific studies which had fascinated him before his interests had been submerged in a life which for a time had been devoted too largely to reckless pleasure.

IV

We should not proceed further with our comparison without noting that neither of the men whose birth is to-day celebrated by the American Society of Naturalists was an avowed naturalist in the more classical sense of the term nor a professional biologist in its modern interpretation.

I have searched in vain through Galton's accounts of his travels for evidence of a compelling interest in the peculiarities of the plants and animals of the extensive region which he opened up to geographical knowledge by his early explorations. He seems never to have described a species, or even to have collected them. His name is represented in the literature of taxonomy only by the South African genus *Galtonia*, of the French botanist Decaisne. It is perhaps significant that as an explorer Galton's natural history observation dealt not with the fascinating superficial forms of the organisms which he encountered, but with animal and human behavior.

Mendel may have been more under the influence of the biology of his own time. He wrote notes on *Scoplia* and *Bruchus* as a student. He was apparently influenced to some extent by the work of other experimental breeders. His materials were at least varied. While his chief work was with plants he devoted much energy to an attempted study of inheritance in bees.

In so far as they considered living organisms the attitude of both Galton and Mendel was more like that of the modern biologist than that of the earlier naturalist.

It is not difficult to establish this, to the complete satisfaction of geneticists, for the Abbot Mendel's greatest contribution, that on inheritance in peas, still stands as a model for much of the modern work in genetics.

Because of the greater number and the wider scope of his publications it is not so easy to pass upon the work of Galton. I fear that many of the members of this audience are unaware of the wealth of Galton's contributions. It will facilitate our subsequent discussion to detail a few of his activities. For the moment I shall limit attention to those which have an immediate bearing on modern biology. His studies of finger prints laid the scientific foundation for a widely applied means of penal and military identification. His early attempts to influence the character of the offspring by the transfusion of blood were essentially modern in their experimental viewpoint. Anthropometric laboratories owe their origin to his interest in human faculties and still profit by his early-devised methods. His studies of the inheritance of physical and mental characters, given to the world over a half a century ago, still furnish, when coupled with an attempt at Mendelian analysis, the model for much of what passes for research in eugenics. Finally, his contributions to the application of mathematical methods in the biological field have had so great an influence that they must be reserved for separate discussion in a later section.

V

The suggestion will inevitably be offered that the work of Galton and Mendel was of the nature of modern biology rather than of the older natural history of their day because of the fact that their pioneer work determined to an appreciable degree the lines along which modern biology has evolved.

Herein lies one of the most interesting points of comparison between Mendel and Galton, and one concerning which there will probably be little differences of opinion among the majority of this audience.

To those who view the vast output of genetic investigation—evident alike in our journals and in our scientific programs—there may seem no reasonable doubt that Mendel has had a more profound and far-reaching influence on biology than Galton.

I have no desire whatsoever to quarrel with the far superior numbers who hold this opinion. I would, however, like to have the facts candidly and judiciously examined.

No one can deny that Mendel's influence on biology—assuming for the sake of argument that the development of modern genetics is to be attributed largely to the influence of Mendel—is conspicuous because of the fact that it has resulted in a narrow and highly unified field of work. Galton's influence was much more varied.

Let us for the moment disregard the broader aspects of biology and of science and limit our attention to the field of genetics, as it has been influenced by the work of Mendel.

Has Mendel's influence transcended or even equalled that of Galton?

Mendel had a relatively small and certainly only an ephemeral personal influence upon the biology or biologists of his time. His published work was, practically speaking, without influence on biology for three decades. Notwithstanding this fact a number of biologists were at the time of the "Rediscovery" more or less actively engaged in experimental breeding. Three have been recognized as co-rediscoverers, and others have been known to modestly lay claim to having been near the great honor. This widespread interest and activity in the experimental attack on the problems of what we to-day call genetics can not have been a matter of accident.

I venture to suggest that there were three groups of influences which determined these activities; the lingering interest in the studies of the earlier experimental breeders; the rapidly increasing economic importance of plant and animal breeding, and the personal influence of Francis Galton and of his writings.

Let us leave for the historian the decision as to which of these was the most important factor. It is sufficient for our purpose to

recall that while Mendel's paper lay unheeded Galton's pen was influencing public opinion and scientific thought. His volumes did not stand with uncut pages. They were read and annotated. "Hereditary Genius," while foreshadowed by essays[3] appearing in the same year that Mendel's paper was read, was first published in 1869. An American edition was issued in 1870, and again in 1891. A revised English edition was prepared in 1892.[4]

While "English Men of Science" might be assumed to be primarily of national rather than of international interest, the English edition of 1874 was followed by an American reprint of 1875. His more technical volumes were issued in only one edition, but were widely read. They appealed to the more intelligent general reader, and they influenced the thought of the specialist. The volumes of Bateson and de Vries issued prior to the "Rediscovery" bear witness to their influence. Whitman's personal copies of "Natural Inheritance" bear evidence of intensive study. A perusal of the "Foundations of Zoology," penned in part over a quarter of a century ago, shows clearly how great was the influence of Galton on the thoughts of such a leader as W. K. Brooks.[5]

Nor was Galton's influence limited to that of his own writings. Weldon's earlier papers had appeared, and biology was beginning to feel the influence of Karl Pearson's pen. These were, to be sure, largely independent, but they showed, and their authors gladly admitted, Francis Galton's friendly influence.

Whether Galton and Pearson were wrong in regard to theories of heredity, or in their method of attack upon the problem of inheritance, does not concern us here. The thing which is of real importance for our present consideration is that fact that in 1901 the scientific world was ready to replace speculation on inheritance by inductive research. Some force or forces led to the profound changes in biological thought between 1866 and 1901. Certainly these changes, which may have been greater than those which have taken place since Mendel's work received recognition, were not due to Mendel. I venture to express the conviction that among these forces one of the most powerful was the direct and indirect influence of Francis Galton.

It was no fault of Mendel that the circumstances of the "Rediscovery" and subsequent events have tended to obscure the in-

3 Galton, F.: "Hereditary talent and character," *Macmillan's Mag.*, 12, 157-166, 318-327, 1865.

4 An important prefatory chapter in this edition gives Galton's impressions of the activities of the twenty-three years which had elapsed since the appearance of the original edition.

5 While Brooks did not always agree with Galton, he wrote: "My own debt to Galton is great, and it is acknowledged with gratitude."

fluence of Galton. The practically simultaneous announcements of Correns, Tschermak and de Vries, coupled with the discovery that Mendel had preceded them by three decades, made a spectacular setting for the new field of experimentation—a staging which was further illuminated by Bateson's controversial writings.[6]

Thus the circumstances of the "Rediscovery" were such as to place Mendel at once in the most conspicuous place on the biological stage.

From 1869 when "Hereditary Genius" appeared until 1889 when "Natural Inheritance" was given to the world and to 1901, which marked the founding of a special journal for the statistical investigation of biological problems, Francis Galton had prepared the professional and the lay mind foı a dominant interest in heredity. In 1901 the seed of the "Rediscovery" fell in fertile and well-tilled soil, and Mendel reaped where Galton and his co-workers had cleared and tilled.

VI

We have already considered in a preliminary way the influence of Galton and Mendel on genetics. Mendel's direct influence has extended little beyond this one phase of biology. Galton's work and influence in biology and in science were much broader. Few biologists realize their scope, or their importance.

VII

First of all, Galton early won recognition as an explorer. While Mendel was completing his studies at Vienna, Galton was traversing the land of the Namaquas, the Damaras and the Ovampo. His trail led him over a thousand miles into tropical Southwest Africa. The regions which he traversed were mapped on the same plate which gave to the world the geographical results of some of Livingston's explorations.

It is our loss that we can not stay to review some of the fascinating chapters of his "Tropical South Africa,"[7] a volume in which

[6] Those who know the history of biology in the quarter of a century now coming toward an end must realize that the simultaneous rediscovery of Mendel's principles by three different investigators lead to an emphasis upon the priority of Mendel's work which would not have been laid if only one more recent worker had observed the agreement between the frequencies of individuals of different classes in the segregated generation and those given by permutation formulæ.

[7] Galton, F.: "The Narrative of an Explorer in Tropical South Africa," London, Murray, 1853. The first edition was quickly exhausted, but a reprint, with a few changes, was issued in the *Minerva Library of Famous Books* in 1889. A valuable appendix, prepared by Mr. Galton, gives additional information of interest obtained during the thirty-six years which had elapsed since the preparation of the original volume.

the hardships and adventures of the twenty months of exploration are subordinated to serious observations on the peoples and their customs.

Impaired health could not prevent Francis Galton from contributing to the advancement of geographical science, though it did lead him to decline the opportunities for further African exploration. His editorship on "Vacation Tourists" was of but short duration, but the contents of the three volumes justified the editor's suggestion that "scientific tours offer an endless variety of results." His "Art of Travel,"[8] while in a sense a compilation, in part from the literature and in part from the personal experiences of the great explorers of his time (with whom he was in intimate association), is truly remarkable not merely in clearness, conciseness and comprehensiveness, but in conception.

In evaluating the significance of his conception we must not forget that the volume was prepared at a time when the Royal Geographical Society was but twenty-five years old, when only the margins of great continental areas were even roughly mapped, and when vast wildernesses, including much of our own fertile domain, were open for colonization. Writing at this time—which was long before the acceptance of the idea that technical training might constitute a part of education—Galton wrote in his preface to the second edition:

> I am convinced that the Art of Travel, or of campaigning, admits of being taught, . . . It therefore seems to me, though I may perhaps be considered an enthusiast by many, that every intelligent youth who seeks a commission in the army, or to become an emigrant, or a missionary, should find his time and energy well spent in learning to use the axe, saw and chisel, the soil needle, the cobbler's awl, the blacksmith's hammer and the tinsmith's soldering iron together with the greater part of the bush manufactures and makeshifts of which this volume treats.

That the volume fulfilled the necessary requisite of usefulness is perhaps evidenced by the several printings which have been issued.

VIII

Time will not permit a detailed discussion of Francis Galton's work in the physical sciences. His studies can not be judged by the standards of physics and chemistry, for they have had only an insignificant influence upon the development of these sciences. Neither can his contributions be dismissed as the pastimes of an

8 Galton, F.: "The Art of Travel; or Shifts and Contrivances Available in Wild Countries," London, Murray, 1855. Various subsequent editions.

ingenious amateur. Practically without exception they indicate inventive efforts towards the practical application of physical principles in other sciences.[9]

Among such studies we may read by title only his work on a hand heliostat for signaling on sea or land, his principle for the protection of riflemen, stereoscopic maps, spectacles for divers, the conversion of wind charts into passage charts for vessels of known sailing capacities, his work on a drill pantograph, instruments for determining the upper limit of audible sound, composite portraits, photographic measurement of animals, and analytical photography.

Galton's work in the physical sciences was not characterized merely by inventive skill. He was keenly alive to the necessity for the standardization of instruments at a time when little attention was given to this essential outside the physical laboratory, and he gave personal attention to the rating of watches, and the standardization of sextants and clinical thermometers, as well as to administrative work during his long connection with Kew Observatory.

IX

The widespread interest in the weather and the chaotic state of meteorological work at the time of Galton's return from his African explorations were almost inevitably a stimulus to his interest. He saw at once the importance of synchronizing and standardizing observations made at stations as systematically distributed as possible over wide areas. He foresaw instinctively the necessity for a better organization of the data then available if progress was to be made in meteorological investigation.

It will be practically impossible for biologists, accustomed to turning to a wealth of meteorological observations tabulated and mapped in detail for their use in studies of geographical distribution, to realize the conditions which prevailed at this time. Partly for its intrinsic interest and partly for its illustration of Francis Galton's firm grasp of scientific method and the importance of scientific organization and cooperation, I beg permission to quote

[9] His earliest paper, printed after his departure for his early African explorations, in 1849, was on the possibilities of a printing telegraph instrument. The apparatus designed seems never to have been carried beyond the preliminary stages. The point of greatest interest lies in the fact that seventy years ago Galton foresaw clearly the possibilities of house-to-house communication which might result from a system of centrals if the telegraph instrument could be adapted to the use of individuals instead of limited to highly trained operators.

the following from the introduction to his "Meteorographica"[10] of 1863:

A scientific study of the weather on a worthy scale seems to me an impossibility at the present time from want of accessible data. We need meteorographic representations of large areas, as facts to repose upon, as urgently as experimental data are required by students of physical philosophy.

Meteorologists are strangely behindhand in the practise of combining the materials they already possess. There are more than 300 skilled observers, using excellent instruments, scattered over Britain and the continent, who transmit observations taken twice daily to meteorological societies or government institutes. Besides these, are the same number of lighthouse keepers.... Lastly, many observers publish independently. Yet throughout this mass of labor that practise of general combination is absent, which is required to utilize it as it deserves. No means exists of obtaining access to any considerable portion of these observations, without great cost, delay and uncertainty, much less can they be obtained in a "reduced" and never in a meteorographic form. The labor of a meteorologist who studies the changes of the weather is enormous before he can even get his materials into hand and arrive at the starting point of his investigations. In the ordinary course he has to apply, with doubtful chance of success, to upwards of ten meteorological institutes in Britain and Europe, for the favor of access to the original documents received by them, and to fully thirty individuals besides. He has next to procure copies, then to reduce the barometer and thermometer readings to a common measure, and, finally, to project them on a map.

I feel that all this dry, laborious and costly work, which has to be undergone independently by every real student before he can venture a step into the scientific part of his work, is precisely that which should be undertaken by institutes established for the advance of meteorology.

After discussing some of the essential features of meteorological maps he says:

A sustained series of publications of this kind, extending over two or three years, would give an extraordinary impetus to the scientific study of meteorology. They would supply the necessary materials in a manageable form, for arriving at a general knowledge of the distribution of the various elements of the weather; they would afford means of testing the extant theory of "forecasts" with a rigor impossible at the present time, and they would necessarily improve it.

Galton foresaw the desirability and the possibility of international cooperation, for he continued:

If extensive tables of reduced observations were issued in England we might look for the cooperation of meteorological institutes on the continent (who already publish voluminously) in following our example.

After discussing some of the practical problems of international cooperation, he concludes:

Entertaining the views which I have expressed on the necessity of meteorological charts and maps, and feeling confident that no representation of

10 Galton, F.: "Meteorographica, or Methods of mapping the weather"; illustrated by upwards of 600 printed and lithographed diagrams referring to the weather of a large part of Europe. London and Cambridge, 1863.

what *might* be done would influence meteorologists to execute what I have described, as strongly as a practical proof that it *could* be done. I determined to make a trial by myself, and to chart the entire area of Europe, as far as meteorological stations extend, during one entire month . . .

In evaluating the conception we must not forget the time at which it was written: It was two years before the two essays which furnished the first published intimation of "Hereditary Genius" and before Mendel's paper was read. It was at a time when for our own meteorological records we were depending upon the journals of our exploring expeditions and surveys, upon the observations of our medical officers at the army posts, and upon such systematic records as the Smithsonian Institution could assemble. Thus Galton's personally printed weather maps preceded by over twenty years our first tridaily meteorological maps.[11]

But we must hasten on; it is not our purpose to detail before a biological audience his various activities in the development of modern meteorology, during the more than thirty-four years of his activities at Kew Observatory and in the Meteorological Office.

In writing to Mr. Galton upon his resignation from the Meteorological Office Sir Richard Strachey said:

It is no exaggeration to say that almost every room in the office and all its records give unmistakable evidence of the active share you have always taken in the direction of the operations of the office. The council feel that the same high order of intelligence and inventive faculty has characterized your work in meteorology that has been so conspicuous in many other directions, and has long become known and appreciated in all centers of intellectual activity.

I am not pretending that Francis Galton was great as a meteorologist. His work came too late in the development of the science to appear alongside that of Galileo where it might be expected in the indices of modern text-books. His personal work came too early to be connected with much of the modern development which has resulted from the widespread establishment of stations which he foresaw as an essential to the practical use of meteorological observations in the protection of shipping. It is not unreasonable to suppose that Galton's work will have greater influence upon the future development of meteorology than it has in the past, for the methods of correlation, regression and partial correlation are now being introduced into the treatment of meteorological data.

Looking back on these phases of Mr. Galton's public service,

[11] U. S. War Department, Office of the Chief Signal Officer: *Tridaily Meteorological Record*, issued from the Office of the Chief Signal Officer. The charts begin with January, 1878, but were not published until 1884.

we as naturalists can not but regret that it absorbed energy which might have been devoted to studies of inheritance, and to the problems of eugenics.

But let us not forget that the scientific man is a citizen as well as an investigator. Mr. Galton's gift of time and thought to administrative duties curtailed his list of books and papers.

Have they curtailed his influence upon the progress of science?

I have touched as lightly as possible on those achievements of Galton which had no counterpart in Mendel's work, in part because I have wished to avoid any possible semblance of partiality in the treatment of the two characters and in part because I have desired to reserve the time for a discussion of the broader aspects of Galton's biological work.

In Galton's narrative of his African explorations there is, as I have said, little to indicate a keen interest in the flora or fauna, other than the big game. There are, however, unmistakable evidences of interest in man. To Galton the loss of valuable equipment was not merely a difficulty to be overcome. It was an opportunity to study the behavior of primitive peoples, by pitting one tribe against another in the recovery of his lost property.

In his later life this interest made itself felt in four interrelated fields of work—in anthropology, in psychology, in heredity and in eugenics.

Galton's studies in these four fields are so closely interrelated that in noting his major contributions I shall follow in the main a chronological sequence.

An illustration of the impossibility of separating them is afforded by "Hereditary Genius," his first great biological work, which appeared sixteen years after his "Tropical South Africa," and during the period of his most active interest in meteorology.

"Hereditary Genius," as Mr. Galton tells us, grew out of a purely ethnological inquiry into the peculiarities of diverse races. In 1874 "Hereditary Genius" was supplemented by a volume on "English Men of Science; their Nature and Nurture." In 1883 "Enquiries into Human Faculty" assembled under one cover the observations, experiments and statistical studies of color blindness, capacity for distinguishing shrill sounds, criminality and insanity, gregariousness and slavish instincts, number forms, the sensitiveness of blind and seeing and of savage and civilized individuals and many other interesting topics.

It was during this period that his interest in anthropological measurements and in finger print identification developed. In

1882 he published a plea beginning "When shall we have anthropometric laboratories where a man may from time to time get himself and his children weighed, measured and rightly photographed, and have each of their bodily faculties tested by the best methods known to modern science?" As a result of his interest, an anthropometric laboratory was established. He recognized the possibilities of obtaining materials of value for scientific investigation from measurements carried out in the public schools, and utilized such materials in his own studies.

Coincident with and supplementary to physical measurements were his studies of finger prints.

Galton foresaw the difficulties of the use of the Bertillon system because of the fact that physical measures are correlated. His interest in finger prints as a means of personal identification first became generally known through a lecture delivered before the Royal Institution in 1888. In 1891 he published an extensive memoir in the *Philosophical Transactions*. His books on the subject are "Finger Prints" (1892), "Decipherment of Blurred Finger Prints" (1893) and "Finger Print Directories" (1895).

The consequence for science of these studies is not to be judged by the volume of the data, by the pages published or by the conclusions drawn. Neither will I point to the fact that in our recent world conflagration the possibility of the identification of millions of men depended upon methods for which we are primarily indebted to Galton.

The true importance of his work inheres in more subtle influences. First, these studies contributed, directly and indirectly, to the development of Galton's own grasp of the larger problems which I shall discuss in a moment. Second, they had an immediate influence upon the scientific thought of his own time.

All students of Mendel's life have emphasized the fact that his influence upon his contemporaries was but insignificant.

The case is quite different with Francis Galton. Throughout his life he was active in the affairs of the British Association, the Royal Geographical Society and the Anthropological Institute. During his later years when his own pen was less active his personality was an inspiration to the scientific men with whom he came in contact, and many of them owed their success in no small degree to his kindly interest. They, in their turn, extended his influence. In America, for example, the early development of both experimental psychology and of statistical methods in anthropology is in no small degree due to J. McKeen Cattell's early association with Francis Galton.

It is hardly too much to say that the personal influence of Galton was one of the chief factors in the development of anthro-

pometry from anthropology. His influence upon the development of experimental psychology was probably equally great.

XI

This brings us to what is the next to the most important if not the most important phase of Galton's work and influence.

The facts which any one individual accumulates can generally be discarded without serious loss within a few years after the good which he has done is interred with his bones. While Galton's contribution of facts constitutes a much larger fraction of the literature of biology than does that of Mendel, it has long since been replaced by better or more extensive data and his name rarely appears in the "Literature Cited" of our current journals. Galton's really great contribution was that of method.

Here again we arrive at a certain parallelism between Galton and Mendel. In their influence upon the methodology of science Galton and Mendel had two things in common.

First, they both recognized the value of a direct appeal to experimental or observational facts as contrasted to speculation and authority. They differed in that Mendel appealed to experimentally determined facts, whereas Galton laid greater emphasis upon the statistical analysis of observations and measurements.[12]

Second, both showed biologists the value of replacing the irregularities of observational frequencies by a smooth mathematical formula.[13] A permutation formula—for example, that leading to the 9:3:3:1 ratio—is a mathematical expression fitted to the empirical data just as truly as is the normal curve.[14]

XII

Galton's work in the application of mathematical methods to biological problems extended much farther than the mere description of frequency distributions by mathematical formulæ. He

12 The difference was in no way due to a lack of sympathy on the part of Galton with experimental methods, but rather to his keen interest in man—an organism which is not available for experimentation in the same way as are peas.

13 Probably the greatest difficulty of some of those who preceded Mendel and who almost attained his results was that they could not see the forest because of the trees. The data obscured the laws.

14 An amusing feature of the criticisms of the biometric school by Mendelians is the fact that the critics have failed to realize that the features of both methods of approach which are of the greatest importance in science are the same—namely, the replacement of the confusing irregularities of empirical frequency distributions by the illuminating regularity of mathematical expressions which represent the results with a degree of accuracy which lies within the limits of the probable errors of random sampling.

grasped the important conception that in biology we are chiefly concerned with the degree of interrelationship between the variables with which we have to deal. His conception of correlation and regression, vastly extended and enriched by Pearson of the Biometric School, has given us some of the most powerful tools in biological research.

There is no time at my disposal for a history of biometry, nor is this the occasion for an indication of what biometry has accomplished or what it is capable of accomplishing for biology in the future. It is sufficient for the moment to point out that many thoughtful biologists recognize the fact that the progress of science depends not merely upon the accuracy of measurement and the closeness of control of experimental conditions, but upon the adequacy of the mathematical description and analysis of the observational, assembled toward the solution of a given problem. This was not obvious in Galton's day. He foresaw in part the long and bitter fight which would be necessary to establish mathematical analysis as an essential part of biological investigation, but the campaign fell to the lot of younger men. It is to his glory to have had the vision. It has been the opportunity and the privilege of his followers to wage the battle.

XIII

In many of the comparisons hitherto drawn there is some element of parallelism, however approximate; some semblance of equality, however slight, between the achievements and the influence of Mendel and Galton. When we turn to Galton's greatest potential contribution of human advancement there is no possibility of comparison further than to note the significant fact that it was not the ecclesiastic, Mendel, but it was the biologist, Galton, who had the vision to foresee the possibilities of the improvement of human stocks under present conditions of law and sentiment.

Thus what may become the most fundamental service of science to humanity was not foreseen, or at least not formulated or fostered by one whose vocation was religion but by one whose vocation was science.

Nor was it merely a question of vision. Galton not only foresaw[15] the possibilities of the application of the laws of biological

[15] It is an interesting fact that in his first paper on inheritance (1865) Galton wrote: "The power of man over animal life, in producing whatever variety of form he pleases, is extraordinarily great. It would seem as though the physical structure of future generations was almost as plastic as clay, under control of the breeders' will. It is my desire to show, more pointedly than—so far as I am aware—has been attempted before, that mental qualities are equally under control" (p. 157). On another page of the same essay we

science to the improvement of human stocks, but he had the energy, courage and practical wisdom to make such provision as he could for the realization of his vision. He himself contributed extensively to the research[16] which should precede propaganda[17] and must precede legislation or action. His contribution was not merely the products of his own pen, but the personality drew about him a school whose researches contributed to the advancement of the science in which he was interested as rapidly as the care which such work demands made progress possible. Finally, he provided that the major portion of his private fortune should be devoted to the foundation of the first laboratory for national eugenics, and named as his personal choice for its head one of the ablest and most productive scientific men of our generation.

This is neither the place nor the time to discuss in detail the work of the Galton Laboratory, where the highest ideals of rigorous investigation have been steadfastly maintained, or the status of eugenics as a science. It is enough to say that the interest engendered by the pioneer work of Galton, vigorously forwarded at a later date by the work of Karl Pearson and by the establishment of the Galton Laboratory, has been the direct cause for the establishment of a series of similar institutions throughout the world.

Finally, let us say to the credit of Galton himself that while his earlier writings were too far in advance of their time to receive serious consideration he did not succumb to discouragement. In the later years of his life he might have been the hero of a mob of enthusiasts, but he was willing to be patient and to wait for research to lay the needful foundations.

XIV

Which was the greater man? Which has influenced most profoundly the development of science as we know it to-day? Which

read: "I hence conclude that the improvement of the breed of mankind is no insuperable difficulty. If everybody were to agree upon the race of man being a matter of the very utmost importance, and if the theory of the hereditary transmission of qualities in men were as thoroughly understood as it is in the case of our domestic animals, I see no absurdity in supposing that, in some way or other, the improvement would be carried into effect."

16 Galton's chief volumes have been cited above. It would lead us too far from our purpose to attempt to cite or review the minor papers which show the development of his interest in and appreciation of the problems of eugenics.

17 Galton was aware of the dangers of propaganda. Thirteen years ago, when some of his essays were assembled in a little volume, "Essays on Eugenics," by the Eugenics Education Society, he wrote in the preface: "It is above all things needful for the progress of eugenics that its advocates should move discreetly and claim no more efficacy on its behalf than the future will confirm; otherwise a reaction will be invited."

has set in motion the more important forces for the future development of science?

Personally, I have no shadow of doubt as to the correct answers, but I shall not obtrude my own opinion upon you.

After all, the questions do not demand formal answers. Let us instead content ourselves by repeating a sentence from our introductory remarks: "Both men worked in advance of the science of their own generation. Both have influenced in a profound and far-reaching manner the science of subsequent generations."

It is fitting that the American Society of Naturalists should do them honor.

A PERMANENT MEMORIAL TO GALTON AND MENDEL

By Professor GEORGE H. SHULL
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WHEN the Mendelian principles of heredity were simultaneously rediscovered and promulgated in 1900 by de Vries, Correns and Tschermak, the systematic study of variation and heredity had been already for several years proceeding with vigor along a wholly different line, known as biometry. As increasing numbers of zealous workers in the Mendelian field made it increasingly evident that the principles discovered by Mendel had widespread if not general validity, the inevitable conflict between the Galton-Pearson methods of attack on the problems of genetics and the Mendelian methods engendered much bitterness and even as late as 1909 an "Ardent Mendelian" depicted the devotees of biometry and those of Mendelism as two armies pitted against each other in mortal combat with ultimate victory inevitable for the Mendelians. We can not admit that this picture ever accurately represented the attitude of biometricians or of Mendelians, generally, though in individual cases it may perhaps have been justified.

What a change hath the past decade wrought! With keen satisfaction we bracket together to-day the names of Galton and Mendel with the assurance that in so doing we give offense to no one! *Mendelism has indeed won the victory, but so also has biometry!* And instead of mortal combat, there has come fraternization, mutual understanding, cooperation, even amalgamation, so that to-day the names of Galton and Mendel stand as twin pillars in the basement room of the house of modern biology, which has been christened "Genetics."

To geneticists it is well known that the fundamental concept in both biometry and Mendelian heredity is one and the same concept; to other biologists this may not have been fully appreciated as yet. Both biometry and Mendelian heredity involve the amassing and analysis of statistics, and the analysis in both rests on the assumption of independent assorting of pairs of alternatives. The basic principle of both is the principle known as the "law of chance," a principle which might be less easily misconstrued if it were always spoken of as the "law of probability," since the word "chance" connotes to many the antithesis of causation whereas in reality it assumes that even events which are individually unpredictable are due to the interplay of definite causes. The simplest phase of this principle may be represented by the repeated tossing of a coin which may fall either "head" or "tail." Cases of increasing complexity may be as simply illustrated by the repeated tossing of two coins at a time, then 3 coins at a time, 4 coins at a time, and so on, to any degree of complexity desired. Mathematically, the results are symbolized by the expression $(a+b)^n$ in which a and b may each be assumed to have the value unity. Mendelian phenomena, as practically handled, usually involve only the lower values of n in this formula (the number of allelomorphic pairs) and also generally require that a and b be of such character or magnitude that they may be easily distinguished from each other. Biometry, on the other hand, works ideally with cases in which n is large, and the alternatives represented by a and b are not easily or not at all differentiable. But there is no *natural* line of distinction between cases in which n is small and those in which it is large, nor between the cases in which a and b are easily distinguished and those in which they are not easily or not at all capable of distinction. The combination of biometry and Mendelism in modern genetics has resulted therefore quite naturally from extended experience in both fields with mutual invasion and overlapping.

The significance for modern biology of the introduction of statistical methods has been well discussed by the last preceding speaker and I will attempt to add nothing to this; but rather take occasion to point out a certain interesting parallel and antithesis in the lives of the two men the centenaries of whose births we celebrate to-day.

Not only were Galton and Mendel born in the same year (1822), but they also published their first scientific contributions at nearly the same time, and at a time that must be considered in these days relatively late in life, namely the age of 43. Mendel's classic paper was read in 1865 and printed in 1866, while Galton's first papers on the statistical study of heredity were published in *Mac-*

Millan's Magazine in June and August, 1865, but the existence of these would be now as completely buried in oblivion as was Mendel's paper before the "rediscovery" were it not that they were mentioned by Galton in a book that has lived, entitled "Hereditary Genius," published in 1869.

Aside from the coincidence of these two cardinal dates (their births and the dates of their first publications) in the lives of Galton and Mendel, their biographies are much more striking in their strong contrasts than in their parallelism; for Mendel was the son of a peasant, while Galton was born to a family already well endowed with the results of several generations of energetic commercial life and thrift. Mendel continued but a short time in the execution of genetical experiments after the publication of his greatest paper; Galton continued his studies throughout a long life and contributed books and magazine articles almost to the day of his death, and in his will he endowed a laboratory to continue in perpetuity the type of research which he had inaugurated. Mendel died in 1884 at the age of 62, wholly unknown to the scientific world; Galton, on the other hand, died in 1911 at the ripe age of almost 89 years, and was well laden with the various honors which admiring scientific and governmental organizations could bestow.

There is something fine in the spontaneity which has been shown by scientific organizations, both national and international, in taking cognizance of this centennial year. All the genetical journals and a number of other biological journals have celebrated in one form or another, and several special commemorative programs have been arranged. The most notable of these was the international gathering in Brünn, Czechoslovakia, in September last.

It is to be noted, however, that these various activities represent quite ephemeral manifestations of the great respect and admiration we all feel for Galton and Mendel. The question has been raised whether these sentiments ought not to be expressed in some more enduring form, and the answer has seemed to be inevitably in the affirmative; but what should be the nature of such a memorial?

Tablets of bronze, and busts or statuary of bronze or marble, appropriate locally to mark the places of birth or of labor, are hardly appropriate for us who have in our midst no *places* to thus commemorate in association with the names of these two great spirits. There is left, however, an even better association than that between name and place, to which to attach a memorial, namely, the association between the men and the *work* to which they gave their devotion and which laid the foundations of a new

branch of biological science. It is suggested, therefore, that the best type of memorial is one which will, in perpetuity, promote the sort of scientific activities to which they were devoted.

It is a fact now well known in scientific circles that the research journals are in difficulty, and unable to meet the current needs of research men for the recording and promulgation of their discoveries. It is recognized that this condition seriously menaces rapid progress in scientific discovery. *Genetics*, particularly, has been unable to meet the needs of geneticists who work with color characters, nor has it been able without special gifts either from the authors themselves, or from other outside sources, to publish the expensive tabular matter required in a statistical science. It will be recalled that in Mendel's original study, four of the eight alternative characters which he considered in the garden pea were color characters, and modern geneticists have likewise found pigmentation characters forming a considerable portion of their most instructive research material. Gross verbal descriptions of such pigmentation characters serve fairly well the crude preliminary studies, but as the analyses become sharper and more detailed such verbal descriptions are certain to lose much of their value. It is proposed therefore as a permanent memorial to the founders of the science of genetics to ask for popular subscriptions to a "Galton and Mendel Memorial Fund" the principal of which shall be kept invested in perpetuity, the income from which shall be devoted to the publication of such colored plates and other expensive types of engraving as may be necessary in the illustration of research papers in the journal *Genetics*, and also to defraying in part the cost of publishing necessary tables of statistics.

There is a special reason why this is a particularly appropriate type of memorial for Gregor Mendel. Several suggested explanations have been offered to account for the long submergence of Mendel's magnificent contribution, and all such explanations doubtless have a certain degree of validity, but the explanation which seems most generally acceptable is that of defective publication. It is true that the *Transactions* of the Natural History Society of Brünn were being exchanged with no less than 120 other societies and institutions of similar scope or related purpose; but it is hardly to be doubted that had his paper been published in one of the standard biological periodicals of the day it would not have remained for 35 years unknown to others capable of appreciating its bearing.

The significance of the type of memorial here proposed will become clearer when we consider what becomes of the papers which can not be published in any of our standard journals because of the need for expensive types of illustration, or for unusual quanti-

ties of tabular matter. Some American papers requiring colored plates have been sent to England or Germany and published in foreign journals; but it is obvious that these sources of publication facilities are strictly limited. Probably the greatest number are published without the illustrations and tabulations required for the full realization of their value. A number of papers with colored plates or other expensive engravings have been published as University Bulletins, the method of issue of which is similar to that of Mendel's original paper, and for this reason they may be expected to be less readily accessible as the years go by than if published in a standard journal like *Genetics*. Have we any assurance that we are not burying in this way to-day important contributions which may or may not be rediscovered, several decades hence?

The amount of money needed to meet present requirements of illustration and tabular matter in *Genetics* has been estimated at $50,000 and this sum is therefore set as the goal to be aimed at.

Is it not clear that since the contributions of Galton and Mendel and the science which they founded touch vitally every branch of biology, giving new viewpoints and new outlook, it is proper to invite all biologists and all those interested in the applications of biology to cooperate in the establishment of this Memorial Fund?

A considerable number of contributions ranging from ten to one hundred dollars each have been received already from biologists, as well as from others who, though not biologists themselves, have an interest in the progress of biological discovery. Since it will be impossible to appeal by individual letters to all of the thousands of biologists in the country, each reader who has not already sent a donation is asked to consider this a direct personal appeal for a contribution to the Memorial Fund. The fund will have its proper character as a memorial only if (or in proportion as) the list of donors contains the names of all who understand and appreciate the epoch-making work of Galton and Mendel.

A permanent list of donors will be kept in which the following grades will be maintained: Persons contributing $5,000 or more will be designated Founders; those giving $1,000 or more, Patrons; $100 or more, Supporters; $10 or more, Contributors; and those who give less than $10 will be listed as Associates.

Checks or other valuable securities, such as stocks or bonds, should be made payable to the Galton and Mendel Memorial Fund and sent to the Secretary of the Editorial Board of *Genetics*, George H. Shull, 60 Jefferson Road, Princeton, New Jersey, who will render prompt acknowledgment.

The permanence of the memorial will be insured by placing the

fund in the hands of a conservative Trust Company, and only the income will be used as needed for the purposes stated. Formal acknowledgment will be made whenever any part of this income is used, and provision will be made also that in the event that it can be no longer appropriately used in the manner here designated the fund will pass to the trusteeship of the American Association for the Advancement of Science for reallocation in such manner as will in its judgment best serve as a memorial to Galton and Mendel.

It is believed that this very practical type of memorial will meet the approval of all those who realize that the best memorial to a scientist is one which serves to promote the work in which he was interested. It is also believed that biologists will generally esteem it a privilege to enroll themselves among the admirers of these two great prophets of modern biology—Francis Galton and Gregor Mendel.

PASTEUR, THE MAN[1]

(DEC. 27, 1822—SEPT. 28, 1895)

By DR. ERWIN F. SMITH

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IN every country and every age the really great men are few. By *great* I mean those who in intellectual and moral grandeur tower like mountain peaks above their fellows. The only exceptions are Athens in the time of Pericles and Florence in the Renaissance, when great men abounded. France in the nineteenth century was no exception. If we exclude Napoleon, who really belongs to the eighteenth century, we have Hugo and Pasteur as the great outstanding figures. If we judge these two men by the influence they exerted on their own generation, Hugo would be the greater; but in a long perspective of years Pasteur looms immeasurably larger because of his influence on practical life in many directions. Hugo will always be a great lyric, epic and dramatic poet, the founder of a new school, the poet of democracy and of the future man, the one who came the nearest of any to representing the whole of his time; but theories of versification and theories of all types of artistic and of literary creation vary from age to age and in the long run Hugo, like Balzac, will be only one of many great men who have influenced the trend of intellectual life in a generation. On the other hand, Pasteur's researches on polarization of light, the structure of the molecule and the constitution of matter, on fermentations and the best methods of conserving foods and drinks, his investigation of spontaneous generation, of aërobism and anaërobism, of the cause of human and animal diseases, and his discovery of various methods of controlling such diseases applicable to medicine and to surgery, will bulk larger and larger as time goes on. It is for this reason that men at this time are assembling in all parts of the world to do him honor. It was his immense and unique contribution to human knowledge in a dozen different fields that made Pasteur the companion and equal of kings and emperors and of all the intellectually great men of his time. So much has been written and said and will be written and said soon about the various types of

[1] Read under the auspices of the Graduate Club at Rutgers College, New Brunswick, N. J., December 20, 1922.

new research which Pasteur inaugurated and all the wonderful contributions he made to the advancement of scientific knowledge in new fields that I may be excused if I turn from these things and speak only or chiefly of the kind of man he was, and this especially for the encouragement of students.

Ancestry

Pasteur was a plain man of the common people. He came of a prolific race of hardy hill-people, peasants, small farmers, artisans. There were no scholars among them. His father, grandfather and great-grandfather were tanners.

As a young man his father was a conscript and fought under Napoleon in the war in Spain in 1812-13. He was advanced from the ranks to the post of sergeant major and was decorated for bravery. To him as to many another old legionary the emperor was always a kind of demigod. The father was by nature incommunicative, secret, laborious, devout, of a slow reflective spirit, given to melancholy and the inner life, but full of strong feeling, and at times of fierce action—witness the sabre episode. Many of these traits he transmitted to his son, especially his love of labor and his meditative taciturnity alternating with periods of exuberant and dominating speech. The father could read and write and liked to draw and paint. He was an unselfish man, very considerate of others and tender-hearted to animals. He would not hunt, and the sight of a wounded lark made him sick. When Pasteur proposed to give lessons in the Barbet school out of gratitude for favors received, the father writes, "You owe it not for this reason alone but for the sake of others, since thereby the principal may be induced to extend a helping hand to other studious young men without which their future might be compromised." Again he writes: "Start a subscription in your school for those poor Polish exiles who have done so much for us. It would be a good deed." Once more he sends good advice, greatly fearing the corrupting influences of the Latin Quarter of Paris, and his son replies characteristically: "When one has red blood in his veins he remains simple of heart and upright wherever he is. He who has no will power is the one who yields." The father was often worried lest his son's inordinate desire for knowledge, or, as he puts it, "immoderation dans le travail," should overtax his physical powers and once he writes very wisely: "Les moins pressés sont quelquefois les plus sages."

Again, when the son sends home money from Paris, saved from his meager income, the father writes: "For my part I had a thousand times rather you had kept the money for your own needs," but adds, "Very few parents have the good fortune to have

to say such things to their sons in Paris. And so I am pleased with you more than I can tell you."

In 1843 the father writes: "Tell Chappuis [Pasteur's bosom friend interested in philosophy] that I have bottled some of the 1834 bought expressly to drink to the honor of the Normal school in the first vacation. There is more sparkle in these hundred litres than in all the books of philosophy in the world. But as to mathematical formulas [Pasteur's study] I believe there is not any in them. Tell him we shall be glad to drink the first bottle with him. Be always good friends."

Pasteur's mother was the daughter of a gardener accustomed to work in the fields, simple, affectionate, lovable, industrious, imaginative and enthusiastic, or lively, as we might say. Pasteur was the third of five children. They were poor and the days were long and the mother wrote seldom, but always with a wealth of affection for the beloved son who, far away, was winning friends among eminent men and making a great name for himself as a hard-working and brilliant student. In 1848, toward the end of her life, the mother writes: "My dear child: I trust you will have a successful year. Take good care of your health. . . . Have I not a right to be worried, far from you and unable to give you a mother's care? Sometimes I console myself for your absence by reflecting what great good fortune has been mine to have a child who has gained a position which makes him so happy. . . . Whatever happens to you do not grieve. All is a chimèra in this life."

Boyhood and Young Manhood

As a boy Pasteur played about the tannery and the small stream that flowed past it, and in the great wave of homesickness that overtook him when he first went to the Barbet school in Paris in 1838 all his thoughts were on the odor of the tan bark. "I believe I should be well again," he said, "if I could only smell the odor of the tannery." So his good father went to Paris and brought him back to the village where he spent some time before again venturing on the great whirlpool of the outside world and then he went not to Paris but to Besançon, so as to be nearer his home. In these early years he studied and worked and sketched, making many pastels of people he liked, some of which are very good. At 13 his most striking aptitude was a love of drawing.

It has been said that Pasteur was dull in his youth. The same was said of Sir Walter Scott, and in both cases the dulness was in the master and not in the pupil.

Pasteur was not a brilliant student and only his friend Chappuis guessed his future greatness but he was a very persistent student

and he loved books. As a mere boy we read of his buying dictionaries and grammars and proudly writing his name in them, and, a little later, of his reading Silvio Pellico's "My Prisons," X.-B. Saintine's "Picciola," a book that was still famous in my boyhood, Lamartine's "Méditations" and Droz's "Essay on the Art of Being Happy."

Lamartine as a political leader also stirred his enthusiasm and influenced him greatly. At this time in Paris he joined the Garde Nationale, gave to the country all his savings—150 francs—and then, as ever, was strongly patriotic.

Pasteur was graduated bachelor of letters at Besançon in 1840 with the following comments on his standing: "Good in Greek in Plutarch, in Latin in Virgil, good in rhetoric, mediocre in history and geography, good in philosophy, good in French composition and very good in the elements of the sciences."

He was a serious-minded youth, with his thoughts set on high things, and with an unlimited capacity for hard work and a grim determination to succeed. Withal, he was an unselfish youth fond of his family and of his friends. He writes to Chappuis in 1842, "My greatest pleasure is to get letters from you and my own people, so write often, and may your letters be very long ones." He writes to his sisters in 1840 from Besançon: "Work and love each other. When one has learned to work he can not live without it. Besides, everything in the world depends upon it." In another early letter he says: "Almost always hard work leads to success. Three things go hand in hand: will-power, labor, success." To these should be added good judgment, and he was full of that.

At this time he was simple, grave, almost timid, but with a flame of enthusiasm, a worshipper then as ever of noble impulses and great men. You remember what he said to the students at Edinburgh when he was old and famous, and what he wrote of Lavoisier when he was young!

Some early opinions of him are interesting. Pouillet wrote: "I do not know a young man more honest, more laborious and more capable."

Biot said "He illuminates everything he touches." Biot also wrote to the father describing the son as "so good and so distinguished" and adding: "It is the greatest pleasure I can experience in my extreme old age to see young men of talent, active and industrious, who seek to advance in a scientific career, by real labors, solid, long-time followed, and not by miserable intrigues."

Senarmont wrote in 1851: "If he keeps on, what he has found is only the beginning of what he will discover."

The great chemist, J. B. Dumas, said in 1865 when he asked Pasteur to undertake the investigation of the silkworm plague:

"I do not know any one at the present time who represents better than you the spirit of Lavoisier and his method."

THE MAN

Tremendous will power and an insatiable desire for knowledge and especially new knowledge to be obtained by experiment characterized boy and man. Added to this he had intuition and scientific imagination of a high order. Philosophy seemed to him a chimèra. He formed innumerable hypotheses to explain what he saw about him, but only to try these out one after another in the crucible of experiment. Hypotheses come to us in armfuls, he said, but they are of no value unless verified. As Duclaux has said, Pasteur loved great horizons, knew how to discover them and to make himself a part of them. Now he was on the mountain top full of expansive joy and ready to combat the world when some crucial experiment had succeeded beyond his fondest expectation, and again he was in the valley of despondency when all his experiments had failed and the way appeared to be walled up. He observes of a year of failures, "Il faut être un peu fou pour entreprendre ce que j'ai entrepris." Duclaux gives us a striking picture of Pasteur at another such a time. After working for two years on the silkworm plague with varying success he comes in one day utterly dejected and throwing himself down in a chair announces, "We have failed. Everything must be done over. There are *two* diseases!" But discouragements were only temporary with this man. Obstacles, inanimate or human, only seemed to stir him to greater efforts. When he is working on a deep problem in crystallography and is perplexed we hear him cry: "I will work ten years on it if necessary." At another time of discouragement he says: "The essential thing is to do over again all our experiments." In Strasburg he writes to Chappuis: "The nights are too long. I prepare my lectures easily and I have five days a week for the laboratory." To Madam Pasteur, who sees too little of him, he says by way of compensation, "I will make you known to posterity." The woman's side of the case comes out humorously thirty years later in a letter to her daughter: "Your father is absorbed in his thoughts, talks little, sleeps little, rises at dawn, and in one word continues the life I began with him this day thirty-five years ago."

Nothing could draw him away from his researches, yet he did not skimp his teaching. He said, "If I neglect my preparation only a little I teach badly and am obscure."

Pasteur was a pioneer and he had the faults and virtues of the pioneer. He cut roads in every direction through vast territories.

He stands distinctly ahead of Robert Koch both in point of time and of genius and I say this without desiring to minimize in any way the great researches of the latter. Like Spinoza he was intoxicated with his work. "We must never be satisfied," he said, "with what we have already acquired."

He attends a great dinner of chemists given by Thénard in honor of Mitscherlich, who is visiting in Paris, and what he brings away of most value is that there is a factory in Germany where he can get once more the problematic racemic acid. Later he chases all over technical Germany and Austria seeking it. The results of his first three days in Leipsic in 1852 are recorded in a letter to his wife as follows: "Dear Marie: I can not await the end of my researches, but must write you again. Yet I have nothing to tell you except that I have not left the laboratory for three days and all I know of Leipsic is the street that leads from the hotel to the university. I come back at night, get my dinner and go to bed." This is how Pasteur saw Leipsic, but in Dresden he had to wait for a train, and another side of his nature came uppermost, for he says: "I have passed four remarkable hours in the galleries marking the pictures I like +, double +, triple +, and even quadruple +." It would be interesting to know what pictures he liked.

At another time he silences those who ask what practical application he expects from his discoveries with the words of Franklin to other "hard-headed, practical people"—"What use is a baby when it is first born?" If those who derided Franklin and his kite could see what has been done with electricity in modern times they would hide their heads, as would those who sneered at Pasteur.

To another who remarked to Pasteur, "It was a mere chance," he replied, "Chance favors only those who are prepared to take advantage of it."

Soliciting academicians for votes he calls "Un vilain métier."

Pasteur was a man of high ideals and his patience and his power of concentration were remarkable. The diligent in business shall stand before kings! Was ever a truer saying or ever a greater example of it than Pasteur? The curse of the world to-day is the desire to shirk honest, long-continued hard work. No man, no organization, no nation that follows this course, can succeed or endure very long—it is the path to individual and national decay, and a great many persons and groups of persons in various countries are now headed in that direction.

Pasteur hewed to the line through a long series of years and at the close of his life we hear him still saying, "Duty ceases only when the ability to labor is at an end."

He was a good son and brother, a good husband and father, a good friend and neighbor, a penetrating observer and persuasive lecturer, but he was much more, for, especially in the second half of his life, the interests of a sick and suffering humanity were always knocking at the door of his heart and making of him more and more a great philanthropist and humanitarian.

He was a veritable Æneas of filial piety. In 1865 he writes to his wife: "The poor grandfather is no more, and this morning we have placed him in his last resting place at the feet of the poor little Jane. I have thought all day of the goodness of my father. For 30 years I have been his constant and almost sole preoccupation. I owe everything to him. When I was young he withdrew me from bad companions, taught me to work and set before me the example of a very loyal and productive life. By the distinction of his spirit and his character this man was much above his position in life, if we judge things as the world judges. He was not deceived; he knew very well it is the man that honors the position and not the position that honors the man. You did not know him, my dear Marie, in the days when my mother and he toiled so laboriously for their dear children whom they loved so much, for me especially, whose books and months in college and pension at Besançon cost dear. I see him still, my poor father, instructing himself without ceasing in the leisure left from his manual labor, or designing and making wood carvings. He had a passion for knowledge and study. I have seen him studying grammars, pen in hand, comparing them and making notes to have at 40 and 50 what the hard fortune of his early years had refused him. But the books he loved best and read most were those that recalled the facts of the great imperial epoch which he had served in his time on the fields of battle and which had renewed society. Good-bye, my dear Marie, and my dear children. We shall speak often of the grandfather of Arbois."

To a young man of good parts who complained of ill treatment he writes: "The discouragement in your last letter is not worthy of a scientific man. Do your duty as well as you can and don't worry about the rest."

Pasteur was a religious man, born and bred in the Roman Catholic communion and remaining in it all his life, but I have never discovered in him any great liking for ecclesiastics. Their methods were not his. He always insisted on the absolute freedom of the scientific man to investigate truth in every direction without reference to consequences, and untrammelled by any religious or philosophical notions. He said: "Three dominating ideas of an unselfish life are God, country and liberty (1883)."

Science, he said, deals with facts, secondary causes, phenomena.

Search for a first cause is not within the domain of science. He succeeded the indefatigable, great and good Littré in the Academie française, and speaking on Comptism he said:

"Beyond this starry vault, what is there? Other starry skies. So be it! And beyond? The human mind, urged by an invincible force, will never cease to ask: What is there beyond? It serves no purpose to reply: Beyond are limitless spaces and times and grandeurs. No one can understand these words. He who proclaims the existence of the infinite, and none can escape it, accumulates by this affirmation more of the supernatural than there is in all the miracles of all the religions for the notion of the infinite has this double character: It impresses itself on us and it is incomprehensible. When this notion takes hold of the understanding we can only bow down before it. The idea of God is a form of the idea of the infinite. So long as the mystery of the infinite shall weigh upon the human mind, temples of worship will be raised whether the god be called Brahma, Allah, Jehovah or Jesus, and on the floors of these temples, you will see men kneeling, prostrate, swallowed up in the thought of the infinite."[2]

To students he said: "Young men, . . . live in the serene peace of the laboratories and libraries. Ask yourself first: What have I done to repay my education? Then, as you advance: What have I done for my country? And finally, perhaps, you shall have the immense happiness of reflecting that you have contributed in some measure to the progress and well-being of humanity. But whether your efforts are more or less favored by life you should have the right to say as you approach the great end: I have done what I could."[3]

Science went begging in the France of the forties as in every other country. Even the greatest men had meager incomes and mere hovels to work in and yet they produced many and brilliant results. Pasteur received room and board and 300 francs per year for his first work as a teacher and thought that too much money for the services performed. At Strasbourg he bought laboratory equipment out of his own purse (prize money). Even after eight years of teaching in Strasbourg and Lille when he came to be professor and sub-director of science studies in his beloved Normal School in Paris he had no assistant, very little money for apparatus and chemicals, less than the least well-equipped institution in this country can boast, and quarters only to be compared to a stable or a shanty, but he had what many of us lack, namely, an indomitable will and the determination to make the most and the

[2] Academy Discourse, April 27, 1882.

[3] *Jubilee Discourse*, December 27, 1892.

best of everything. Not a little of his early success was due to the kind of friends he made, but he was able to win and keep the friendship of the greatest scientific men of France, such men as Dumas, Biot, Balard, Saint Claire Deville, Claude Bernard and Thénard, only because he was himself genuine, had already made notable discoveries, and gave promise of a brilliant future. From the time he entered the Normal School as student in 1843 until his death in 1895 his life was a long series of triumphs, of splendid discoveries, and of private and public gratulation. All doors were open to him, academies elected him, royal societies honored him, universities invited him to lecture, medical societies gave him honorary membership, surgeons and heads of technical industries consulted him, the Emperor sent for him, the Parliament granted him an annuity for life in recognition of his public services and later doubled it, but through it all he remained the same simple, unaffected, honest man searching for the truth in every direction and especially eager to discover and destroy the causes of the great human and animal plagues which he believed to be due to various undiscovered ferments.

Pasteur has been accused of being callous to the infliction of pain and has been called an "archdevil" by some of our friends and neighbors who love cats and lap-dogs more than they love children and a suffering humanity. But beyond all doubt, like his father, he had a tender heart for all who suffer; and who can measure the alleviation of pain his researches have brought to mankind and to some of those lower forms that have no voice but a cry! A hundred anecdotes show his sympathy both for men and animals. I have space for but one. To-day, death from puerperal fever is the rarest of diseases. In Pasteur's time it was the commonest. Every third mother in some places might expect to die in childbirth. Imagine, if you can, the lecture room of the Academy of Medicine full of learned doctors peering over their spectacles in amazement at his temerity as he interrupted and contradicted one of their greatest, saying, "the cause of this disease is not at all what you think it is, but it is a germ. I have seen it, and this is its shape [drawing it] and you carry the disease from patient to patient on your hands and on your instruments." What should a young chemist know about puerperal fever! yet he was right and they were wrong, and in his vision he saw a multitude of mothers needlessly sacrificed who could be saved and now are saved. Should not the women of to-day rise up and call him blessed? Yea, verily! Suppose he destroyed some experimental animals in learning this great truth. We destroy multitudes of animals, and often very painfully, merely to wear feathers on our hats, furs on our backs and gloves on our hands or to eat more

flesh than is good for us, and often, too, for the mere pleasure of the killing, as in a great deal of hunting and fishing; but he and his kind, down to this very day, only for a large service to humanity and to the domestic animals. Small wonder, too, that he was earnest almost to rudeness before these doctors, as frequently in other discussions, when he saw the truth set aside and error exalted. He was a rude and fierce debater, and one polemic followed another in quick succession. The love of truth compelled him, a certain inheritance drove him. To opponents of his crystallographical views he shouts: "If you know these things, where is your conscience? If you do not know them, why do you meddle with them?" And afterwards, as they went home together, Duclaux made him laugh by saying: "I half expected to see you throw the models[4] at their heads." Again he says of Pouchet and his followers: "I have the truth on my side. They do not know how to experiment. It is not an easy art."

I could multiply such examples. There are many in Duclaux's wonderful book, "Pasteur, the History of a Mind," and in Rene Vallery-Radot's "Life of Pasteur," both now available in English. Pasteur Vallery-Radot, the grandson, is also editing a definitive edition of the writings of Pasteur, something long needed.

In addition I have only time to touch for a few moments on some of the high lights in his scientific progress. Pasteur began as a chemist, he finished his career as a human pathologist. Along the way he was a physicist, a mineralogist, a microscopist, a histologist, a mycologist, a bacteriologist and a protozoologist. He studied all kinds of fermentations that came to his hand, alcoholic, acetic, lactic, succinic, butyric, and types of microorganisms (aërobic or anaërobic) that are involved. Milk, beer, wine, vinegar and the decay of meats, fruits and vegetables interested him by turns. He and his students revolutionized the dairy industry, beer brewing, wine-making and the production of vinegar. The study of the diseases of silkworms led him to anthrax and chicken cholera and wound-infections, and these led him to rabies; and all these studies led him to vaccines and sterilization by heat and by germicides and gave him wonderful glimpses of a promised land which we have begun to enter into and occupy, but the wonder and wealth of which are still only imperfectly realized, especially as related to the public health. In his book on "Diseases of Silkworms" (Tome I, page 99), Pasteur says: "It is within man's power to rid the world of parasitic diseases, if, as I believe, the doctrine of spontaneous generation is false." So vast was his dream! We shall never quite accomplish the extinction of any

[4] Gigantic models of his crystals.

parasitic disease, there are so many unsuspected carriers of disease and other uncontrollable factors involved (inheritance, for example,) but we have already reduced some of the great scourges of mankind to small proportions, *e. g.*, smallpox and yellow fever, and many other similar triumphs must follow when the public are willing to trust the scientific man and put into practice what he already knows. Pasteur glimpsed all this.

Much of his work, of course, was done by means of assistants but he was the man at the helm. We are filled with amazement at what he accomplished, especially when we remember his handicap. His mother died of apoplexy and he suffered a hemiplegia of the left side when he was in the midst of his silkworm studies in 1868, so that for some days his life was despaired of but gradually he recovered and was able to limp about, undismayed and thrice determined. Indeed, all his greatest work was done in the 27 years that followed the first paralytic stroke which would have been a knockout blow for most men. He is a great example of will-power directed to noble ends.

Finally, when so many things are being said against France, it is well to recall not only what she has endured but what she has given to the world. To me she is to-day intellectually and morally and scientifically the greatest nation on the continent of Europe and I resent anything said against her. Rather let us praise her fortitude, glory in her great men and join hands with her whenever we can.

FURRED FOREST PLANTERS

By Dr. J. V. HOFMANN
WIND RIVER FOREST EXPERIMENT STATION

THE forester must provide for the utilization of the forest and, at the same time, insure its perpetuity. The manifold factors which influence regeneration must be known and their direct or indirect effects considered in any attempt to control or insure regeneration. These factors may be climatic, edaphic, or biotic. Unfortunately, the biotic factors have generally been classed among the destructive factors, and the rodents and some species of the bird population of the forest have come to be considered nuisances and their extermination ruthlessly advocated. Those whose forest visits and camp life have been made miserable by the aggressive companionable natures of these woodland inhabitants have a personal grudge to settle, and those who have seen their favorite plantings of seed serve as a festive celebration at which, apparently, no race or color lines were drawn can tolerate no leniency in their sentence. This "hard-boiled" lot is joined by the group who have made their plans to collect forest tree seeds and then found the program of the rodents was along the same line at a considerably earlier date.

This antagonistic feeling has become so deep seated that the rodent is condemned without the committal of an overt act. Here the old adage that "a little knowledge is a dangerous thing" should be revived and the rodent given a fair and impartial trial for his life.

The gray squirrel is condemned in California because it destroys practically all of the sugar pine seed. This fact is easily checked and need not be questioned. Yet reproduction of sugar pine has become established there in the past as have also the present stands of timber of this species. These stands were very probably planted by the squirrels, and the reason that reproduction fails in these regions now may be due to the unbalanced relation of the number of squirrels and amount of seed produced. It is a well-known fact that rodents will cache supplies which they depend upon for food during the year; consequently, for reproduction, there must be a surplus of seed over and above the food supply of the rodent population.

A change of equilibrium may be brought about by the destruction of the rodent's enemies, such as hawks, owls, weasels, snakes, bobcats, badgers, skunks, minks, coyotes, etc., and also by reducing the number of seed trees to the point where the supply of seed does not exceed the demand.

The distribution of the black walnut is attributed almost entirely to rodents. The reproduction from cached nuts in open tufts of grass or near logs and stumps are direct evidence of rodent activities. The same condition is evident with other nut-bearing species, such as the oaks, hickory, etc. Where seedling of those species occur on slopes above the parent tree and in localities where there is no immediate other source of seed, it is plain that the rodent has contributed a part of his stored food to the cause of forestry.

Distribution of western yellow pine in Montana, Idaho and Oregon has been found to be due in many instances to seed cached by rodents. Mice are very instrumental in this work because they cache individual seeds rather than cones. Chipmunks do this also by selecting a different place for caching each mouthful of seed which they gather. In this manner the yellow pine seedlings become established on the grassy slopes where seed that merely falls on the surface would not have a chance for establishment.

Direct seeding of coniferous species has been practically abandoned in the National Forests, due almost exclusively to the destruction of the seed by rodents. In all experiments the results have shown that the number of rodents present on the areas would consume many times the amount of seed sown. Poisoning has been partially successful on local areas but has not been found practical. On the Pike National Forest in Colorado caches of poisoned grain of one pound and less were found. This shows the instinct for hoarding even before a full meal has been eaten.

In the Douglas fir forests of the Pacific Northwest rodent life is very abundant and is an important factor in forest management. Research has determined that the even-aged stands of reproduction, which occur over large areas after forest fires, are due to seed which was stored in the forest floor before the fire and retained its viability through the fire. That this seed storage is in a large part due to the rodents is emphasized by the occurrence of reproduction in groups from caches in some instances, and most strikingly by the occurrence of stands having up to 40,000 seedlings per acre where all the litter and duff has been consumed by fire and no seed trees are left on the area.

This was found to be the condition on the Cispus burn of June, 1918, when examined in July and August, 1919. This fire covered

about 150 square miles north and west of Mount Adams on the Rainier National Forest. The fire occurred so early in the season that there was no possibility of seed production in 1918. The area burned over included largely a 1902 burn which had restocked generally with a good stand of reproduction.

In the 1902 fire some groups of trees escaped which remained green until the fire of 1918. Where these isolated groups of trees were killed in 1918 there was no source of seed left except that which had been produced in 1917 or earlier by these trees. Good reproduction occurred under such groups of killed trees, but not out from them, even where the duff was completely burned and the surface of the light pumice soil showed that it had been severely burned. Seed which had merely fallen from the trees would have had no chance of escaping such a fire because it would have been in the litter and humus. The present stands of young growth occurring on these areas, therefore, must be credited almost entirely to rodent-cached seed before the fire which was planted deep enough to escape the fire. The planting of seed in the mineral soil is also a decided advantage in the establishment of the seedlings in such localities.

During the dry season the surface soil dries out to a point where the water content is less than the requirement of seedlings; consequently, it is essential that the seedlings form deep root systems before the dry season. Seedlings in the mineral soil have a better chance to develop deep root system than those that germinate on top of the duff.

During the caching of seed a large per cent. of the crop is eaten, and in years of light seed production there is probably very little left, excepting such caches as can not again be located.

Tests have shown that humus is among the most effective mediums for disguising the odor of seed. When seed was covered with one and one half inches or more of duff mice would generally miss it, although in mineral soil they would find it at the same depth. This would have direct application in caches which were left beneath the duff in the fall and all traces of which had been obliterated by snow and rain before spring.

Rodent activity often accounts for the lack of reproduction from scattered single seed trees. The failure of seeding from single seed trees has been noted in many instances in the Douglas fir region, also on the Pike National Forest and Minnesota National Forest. The white-footed mouse of the Cascade region has been found to consume 300 Douglas fir seeds per day, and the chipmunk 600 seeds per day. From these figures it is readily seen that only a few rodents would consume the entire crop of seed from

scattered seed trees where the average seed production is 20,000 seeds per tree as is true in this region.

Rodents, apparently, do not carry seed to any great distance; consequently, they can not be depended upon to restock areas which are cut over or burned at distances more than about 300 feet from seed trees. Single instances of distribution to great distances by birds or animals no doubt occur.

The close relationship of the animal life of the forest and the forest itself brings out clearly the benefits which each derives from the other, and also emphasizes the broad general interdependence, while the problems of control and damage are local and specific.

The benefits of rodent activity in the regeneration of forests are usually indirect and not as noticeable as the damage, and too often judgment is passed where only the destructiveness of the rodents is considered. These factors should be carefully investigated and weighed against one another before the rodent is pronounced a nuisance or a benefactor in any forest region.

While the rodent has been considered the enemy of the forester, it is evident that he has played a large constructive part in the success of the natural regeneration of forests.

CERTAIN ECONOMIC REACTIONS OF THE WAR[1]

By Professor JAMES MAVOR
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STUDY of reactions of a specific force upon any system involves preliminary estimates of the character of the system before the force in question began to act upon it. The conditions of this address render a serious survey impracticable. I shall therefore assume a general knowledge of the character of the European and American economic systems as they were when the outbreak of war occurred; but I wish to direct attention briefly to the following:

Growth and Movements of Population

The population of Europe grew during the past fifty years at the average rate of about one per cent. per annum; towards the close of the period, the rate exhibited a tendency to increase. The rate of increase of urban population was much greater than that of rural population, even in countries predominantly agricultural like Denmark. Emigration from some countries, notably Germany, declined in the fourth quarter of the nineteenth century. Emigration from Austria and Italy declined during the first half of the second decade of the twentieth.

Periodical migrations assumed large proportions. Thus, about a million Italian *contadini* customarily left Piedmont and Lombardy every year for the South of France to assist in the harvest, and a similar number of Russian laborers customarily left Russia for Germany for the same purpose, both large groups returning when the harvests in the respective countries were over. Within the countries mentioned, Germany, France, Russia and Italy, there was also extensive temporary migration during harvest time.

Development of Transportation

While movements of population do not necessarily depend upon transportation facilities, for many of the great migrations of history have been conducted with the most slender means, railways and steamships have facilitated these movements, especially from

[1] Address of the vice-president and chairman of the Section of the Social and Economic Sciences, American Association for the Advancement of Science, Boston, December, 1922.

Europe to America. The pressure of population in Austria, for example, and particularly in Galicia, was materially relieved by the cheap zone tariff on the Austrian railways and by extremely low competitive fares on connecting railway lines and on ocean steamers. It was possible for Galician peasants to emigrate, even although they possessed almost no capital. Their emigration relieved the pressure of population, raised the wages and standard of comfort of those who remained and contributed to reduction of land rents. In Southern Italy emigration had the same consequences.

Demand for Commodities

Increase of urban population in every country in Europe in greater proportion than the increase of rural population involved increased industrialization, and although wages were naturally influenced by the growing stream of workers, the means of the latter were enhanced and therefore their capacity for consumption became greater and more varied than it had been in the self-contained rural villages. Increased profits arising from increased production rendered possible by the influx of laborers enlarged the means of the middle classes and enabled them to live at a higher standard of comfort than that to which they were formerly habituated. Thus manufactures, imports and exports were subject to rapid increase during the fifty years immediately preceding the war.

The industrialization of Europe meant increasing dependence for food upon less highly industrialized regions. Imports of wheat, rice, tea, coffee, sheep and cattle from North and South America, China, Japan, India, Australasia and North and South Africa formed a large proportion of the foodstuffs of Europe.

An industrial community requires not alone food, but also raw materials. The more complex industry becomes the more widely extended must be the area from which these materials are drawn. Many of the raw materials of modern industry are drawn like rubber and cotton from tropical or semi-tropical countries, or like timber from regions remote from the seat of the industry. If the supply of raw materials fails for any reason, unemployment ensues and a strain is imposed upon the social system. The danger of such a situation was not unforeseen; *e. g.*, the British government appointed in 1903 a commission on food supply in time of war. This commission published in 1905 a series of valuable reports which showed how narrow a margin of safety existed in a highly industrialized country like Great Britain. The commission found that in 1870 the proportion of imports to consumption of wheat was 1.4 per cent.; in 1880, 8 per cent., and in 1900, 25 per cent. It

was also found that in only four years out of eleven years immediately preceding 1904 was there always a sufficient supply of wheat in warehouses at the ports to provide for two and a half weeks consumption. Germany and France were not industrialized to the same extent as Great Britain, yet they were vulnerable in the same way. In these countries, also, the urban population had grown at the expense of the rural, the production of foodstuffs had relatively declined, imported foodstuffs and raw materials were composing increasing proportions of the total consumption.

Even in times of peace, the margin of safety was small. Any disturbance from the normal flow of commodities produced hardship. Thus in Great Britain there was a sharp scarcity of wheat in consequence of the Leiter operations in wheat in the Chicago market in 1898, the supply being affected from June to August of that year.

Movements of Prices

The characteristic of the period of about seventy years from the close of the Napoleonic Wars till the middle eighties was decline of prices. The purchasing power of gold increased steadily, notwithstanding the increase in the production of gold which began in 1849.

From the middle eighties until 1914, a period of about thirty years, the purchasing power of gold diminished, prices became higher owing in general to two concurrent causes—the increase of demand for commodities without proportionate increase in production and the increase in the amount of gold available for purposes of circulation.

The Currency Systems

Increase in the production of gold from 1886 enabled European governments and European bankers to accumulate gold reserves to a much greater aggregate amount than had previously been possible. The currencies of Russia, Austria and Italy had been depreciated on the foreign exchanges for many years. By the beginning of the twentieth century the currencies of all these countries reached the par of exchange. Great Britain has for a long period adopted the policy of merchandizing gold rather than storing it. Her bankers have looked upon dealing in gold as more profitable than keeping unnecessarily large stocks of it. France has for long adopted the policy of warehousing gold and of checking exportation of it by imposing a premium when gold is withdrawn for export. The other continental countries in general followed the example of France. The possession of large gold reserves against their issues of paper currency gave the cur-

rency of all of the European countries stability and the fluctuations in exchange were due entirely to the demand and supply of the instruments of exchange from day to day. These fluctuations were not caused by increase in issues of paper, because these increases, when they did take place in obedience to public demand for them, were based upon a sufficient gold reserve to remove any doubt as to their convertibility into gold if the holder so desired.

Wages and Conditions of Labor

The influx of laborers into the towns which was going on with accelerating speed towards the close of the period tended to keep wages down in spite of the demand for commodities. In those countries in which the cities were not readily susceptible of rapid expansion, the conditions under which the laborers lived were often deplorable. Even in those countries where public authority, private enterprise or private benevolence grappled with the question, there was much overcrowding in the industrial centers and a very definite tendency towards deterioration of the industrial population. Newcomers did not easily adjust themselves to the life of the city, and even if they could have done so the conditions of the city were not favorable for rapid absorption of increasing numbers. By the close of the period real wages had in general increased with the increase in the production of commodities and some of the causes of fluctuation of employment had been brought under control by skilful administration of industrial enterprises. Limitation of the hours of labor of women and children by law had been provided by the earlier factory acts; but the principle had not been extended to adult male labor. Demands for an eight-hour day in certain industries began to be formulated, especially in England. Later these demands became almost universal throughout Europe. So also demands for the institution of a legal minimum wage were advanced in many countries. By 1914 these projects were being urgently pressed by the representatives of labor. It appeared as though the industrial world was returning to the restrictive conditions of the 18th century.

Labor Movements

By labor movements, I mean the grouping of laborers in trade unions or other forms of combination for the purpose of making collective demands or arriving at collective bargains. For the first half of the past hundred years, combinations of laborers were forbidden or discouraged in almost all countries. So also were combinations of capitalists. Both were forbidden on the ground that society as a whole might suffer through combined action resulting in what was regarded as artificial conditions in which

wages and prices were higher than they would have been had there been no such combination. About fifty years ago the legal obstacles which were in the way of joint stock enterprises were removed and although some of the restrictions upon the employment of capital remained upon the statute books of most countries, even these fell into desuetude. Legal restrictions upon labor combinations remained longer, but in the third quarter of the nineteenth century they disappeared in England. Labor movements in all countries were given at this time a great impetus. Almost all these movements led to the emergence of two factions—one faction insisting that in order to improve their condition it was necessary for the laborers to influence or even to control legislative bodies and governments, and the other that the laborers should not concern themselves with politics but should devote themselves to the promotion of economic means for the improvement of their position. The first faction leaned towards collectivism or towards a proletarian government which might or might not be collectivist, and the second towards trade unionism, towards strikes or towards syndicalism or even towards *"l'action direct."*

Movements of Capital

By this I do not mean a capitalist movement as opposed to a labor movement, but the movements of capital from one country to another and also certain changes in the manipulation of capital which characterized the period immediately before the war. The transference of capital on a very large scale from Great Britain and France to other countries had been going on for about fifty years up till 1914. I need not trouble you with statistics of these investments; they can be readily obtained from the customary authorities. The field for investment in Great Britain and France, though large, is, nevertheless, comparatively limited, and the former especially was able to conduct her world-wide trade very largely because of her world-wide investments. Great Britain supplied the greater part of the capital by means of which the American railway system was recreated after the Civil War and at the same time she was building railways all over Europe. Since then many of the high buildings in the United States cities have been financed by the British insurance companies and other investing institutions. France has also played a conspicuous rôle in furnishing capital for foreign enterprises. The annual increments in the capital available in the market for borrowing which these two great saving countries supplied were to be counted upon and were counted upon in the finances of all countries. Germany also had for some years been accumulating foreign investments. During the whole period of the history of the United States up till 1914

they were borrowers, and there were therefore at that date immense sums of foreign money invested in them.

Changes in the manipulation of capital occurred chiefly in connection with joint-stock enterprise. The corporation took the place of the individual employer, and combinations of employers were followed by combinations of corporations. The formation of very large corporations appeared at times to be determined by economic necessity. Such combinations were not confined to the United States. Trusts in England and *cartels* in Germany were formed in the same manner and for the same objects. So long as these corporations did not come into direct relations with the general public, their formation and the methods with which they conducted their business did not excite any public apprehension. But those corporations, such as the railroads, street railways, electric power and lighting companies and the like, whose services are utilized by every one, were peculiarly open to public criticism and attack. The furore against corporations attained its full vigor about the end of the nineteenth century. Then began reversion to the legislation against combinations of capital which I have noticed as belonging to an earlier time.

Mobility of Property in Land

In the United States, especially during the past fifty years, property in land has been relatively mobile. Land changes hands with frequency. In Europe, this was not generally the case. The possession of landed property was, even in the case of small holdings, hereditary. Ownership of land had a certain honorific value. The landowner enjoyed a social distinction denied by the people in general to those who were not landowners. This condition existed all over Europe, but it was especially observable in Eastern Europe and chiefly in Russia, where the landowners occupied a privileged position under the sanction of the law.

Public Opinion Regarding the Limits of Functions of the State

Public opinion on the functions of the state has been subject to great variations during the past hundred years. At the beginning of the period, the state was looked upon as a necessary evil—an institution which was to be tolerated in the exercise of those functions which could be exercised by the state alone; but every attempted encroachment of the state upon private liberties was to be resisted. The governments of even so-called democratic states were often offenders against liberty; therefore, they should be confined strictly to the sphere which indisputably belonged to them.

The Germans were really the first to take a different view of the state and its functions. This view probably had its real origin in the conception of the unity of the state and in the still earlier

unity of the tribe. The Germans were driven to this view by the poverty and depression of Germany in the period immediately succeeding the Napoleonic wars. The German philosophers of that time, at whose head stood Fichte, saw that the people would never emerge from the pit into which they had fallen without organized means. There was an existing organ whose function might fairly be regarded as including the ordering of the whole life of the people in such a way as to make them economically prosperous and politically stable and powerful. This rudimentary view was developed by Hegel into a state philosophy in which the state became personified into a kind of beneficent Providence, an economist in the sense of energetic housekeeper who managed everything for everybody, who was always at everyone's call for services of all kinds. Undoubtedly for depressed Germany such an idea had its validity and its fruitfulness. By means of it the Germans rose from the dust and became a great and powerful people. But the state is not merely an abstraction; it is a concrete reality, visible in the persons of those who compose the government, and the resources these persons have at their disposal are entrusted to them by the people to whom these resources belong. It is human to err, and governments of states are human. Thus, at times the tangible agents of state action were not always beneficent and efficient housekeepers but often quite otherwise. The state, instead of corresponding to the ideal of Fichte or even to the ideal of Hegel, became an autocratic monster in whose actions it was difficult to discern any of the moral purposes which it was supposed to personify.

England was slow to adopt the German idea of the state as it developed in Germany about the middle of the nineteenth century. Yet by the year 1870 her legislation began to show evidences of change. This change did not pass unnoticed. Herbert Spencer, *e, g.*, denounced it as making for a *"new slavery."* But the extension of the franchise in 1832, 1866 and 1889 had resulted in a new electorate which was little used to abstract discussion about the limits of state functions. They had been endowed with a voice in the government of the state and they intended to ask for what they wanted and they meant to get it. They were not interested in the origins of doctrines; but they were interested in utilizing the machinery of the state for any purpose for which that machinery might be used. There thus began an era of state and municipal enterprise—an era in which what were called public services began to be rendered by state and municipal officials. This era may be said to have extended in Great Britain from about 1870 till about 1903, a period of a generation. Although the enterprises upon which the state and municipality embarked during that gen-

eration have been in general retained, few enterprises embodying any new principle were entered upon by either after that time. The furore for public ownership began later in the United States and lasted longer.

Public Indebtedness and Taxation

The most important and inevitable result of the expansion of state and municipal activities were the expansion of the public debt and of the taxation of the public. All countries which adopted the view of the functions of the state which I have described, either as a reasoned theory or as a ground of practical action, added to the obligations of the state, multiplied the state functionaries and added to the taxation imposed upon the people. Several important consequences followed the adoption of this policy. Fixed capital, that is, capital invested in factories, houses, machinery and the like, was so heavily taxed in Great Britain, for example, that the net returns yielded relatively smaller amounts for foreign investment and so diminished the flow of capital to foreign countries, not absolutely but relatively. Circulating capital, if heavily taxed in one country, tended to flow to another country, where it was not so heavily taxed. Another consequence was that the investment of capital in fixed forms was discouraged, and there thus developed a scarcity of house accommodation and much overcrowding in the growing cities. As regards debt, the competition of public securities in increasing volume with other securities in the market depressed all securities and raised the rate of interest. There was also manifest a tendency towards incurring floating debt in large amounts.

It is now my task to examine with unavoidable brevity the reactions of the war and the peace in these various categories.

Population and Its Movements

During the war the growth of population was affected by the enlistment of all the able-bodied men of practically the whole of Europe. Men of military age were conscripted and were not permitted to leave their countries. Migration was suspended. The losses of the war diminished the population of every country temporarily and prevented growth that would otherwise have taken place. Experience has shown that after great wars populations in general exhibit resilience. They soon repair in a numerical sense the damage. The actual loss of men will thus ere long disappear from census statistics. Yet the loss of the flower of the youth of France, Great Britain and Germany will not soon be overcome. In some districts in all of these countries the losses were so great that a generation or more may elapse before the numbers of the people

through natural growth can recover. There are villages in Scotland in which at the close of the war there were left only aged men, women and infants. The mature able-bodied male population had been wiped out.

In the theatre of war there were important movements of population. Holland and Switzerland were both crowded with French and Belgian and later with Russian refugees. The Belgians and the French population fled from their homes on the advance of the German armies, and the Germans in East Prussia poured into Eastern Germany when the Russians advanced through the Mazurian marshes in the early days of the war. So also the peasants of the plains of Galicia and Bukowina and later those of the Carpathian valleys fled before the Russian advance, abandoning their houses and carrying with them their slender portable belongings. The flight of the Serbian peasants through the mountains of Northern Macedonia when the Austrians advanced into Serbia was one of the most tragic episodes in Balkan history. When Roumania was defeated, Roumanians poured into southern Russia, and poured back again when the Bolshevik revolution compelled them for a second time to become refugees. The Italian farmers were driven back by the advance of the Austrians on the Piave.

All these movements have had important economic consequences for the people concerned in them. Their life was torn up by the roots. Families were disrupted and the products of their own industry and that of their ancestors destroyed by shot and shell. The devastation of their fields has meant the destruction of the fruit of centuries of toil. The fixed agricultural capital and the fixed capital in dwellings together represent the product of practically infinite labor.

Apart from these movements of population as direct consequence of military operations, while the war resulted in the mobilization of armies the population in general became less mobile. Traveling was expensive and troublesome, the movements of troops taking precedence of everything, and the movements of civilians were embarrassed by passport regulations. After the war the treaties of peace altered the map of Europe, cut large areas from Germany, Austria, Hungary and Turkey; in some cases added these areas to already existing countries, as Alsace and Lorraine to France and a part of Schleswig-Holstein to Denmark, or created new countries out of fragments taken from the defeated nations—as Czechoslovakia, compounded of fragments taken from Germany, Austria and Hungary, and Jugo-Slavia, composed of former Balkan states. In each case various considerations impelled the makers of treaties to include this or that people with this or that

nation. It was inevitable that some should be dissatisfied with this arbitrary method of settling the nationality of individuals. Many, therefore, migrated from the region in which they had resided and went to places where they might be associated with their own people. More than a million Germans left Alsace-Lorraine and Upper Silesia for Germany when these regions were detached from the German Reich. Other migrations accompanied by great hardships occurred in Turkey. Deportation of Armenians and expulsion of Greeks, the consequence of the adoption of a new nationalist policy by the Young Turks, of which the slogan is "Turkey for the Mohammedan Turks," led to migrations of hundreds of thousands of people, accompanied by loss of life and sacrifice of property. These movements are apparently not yet over. Greeks are still leaving Turkey and Turks are still leaving western Thrace.

The disorganization of the economic life of these regions is still in progress. Since practically the whole of the trade as well as much of the industry and agriculture of Asia Minor have been carried on by the Greeks and since the Turk is a landed proprietor pure and simple, the economic ruin of Asia Minor is certain, unless, adopting the plan of earlier ages, by means of incessant warfare or by means of reorganization of the African slave trade, which had been put down by Great Britain, the Turk is able to secure the number of slaves necessary to ensure production.

The reaction of the war upon population within the theatre of war has been in short the pulverization of it, its economic life has been destroyed and the people have been dispersed.

Revolution has had a similar influence. The Russian Revolution, owing to its special character, has resulted in the flight of about two million Russians. Of these some have gone to Turkey, where large numbers found a refuge in Constantinople, to Japan, Italy, France, England and America. The flight of so large a number of people has compromised the economic life of Russia and has contributed with other causes to altered character of industry and trade in that country.

In consequence of all these movements, the margin between the birth rate and the death rate, which, apart from migrations, constitutes the natural increase of the population in any area was disturbed in all the European countries.

Transportation

Ocean transportation was paralyzed by the war, partly through the commandeering of shipping for military purposes, partly through blockade, and partly through the losses from the U-boat campaign. On land the railways—where these were in the hands of joint-stock companies—were taken over by the governments. The

railways of all countries were taxed to the utmost in the conveyance of troops and munitions. During the war, shipbuilding went on with unprecedented speed, new railways were built and new telegraph and telephone lines were erected. After the United States went into the war, practically the whole telephone system of France was reorganized by the American Telephone and Telegraph Company.

As the event proved, adequate importance had not been attached to the possibility of an unrestricted submarine campaign against mercantile shipping. The adoption of the U-boat policy by Germany was not carried unanimously. On the contrary, in general the German statesmen are understood to have been opposed to it on account of the political effect.

When the war began the British government brought into operation at once a system of insurance against war risks which had been long before prepared for the contingency of war with a maritime power. The subject had been fully discussed in 1904-5 and a plan was shortly afterwards devised.

In its earlier phases, the submarine inflicted great damage upon shipping and compromised the carrying trade, especially of food and passengers. The conveyance of troops and munitions was never seriously menaced. In time the menace of the U-boat was diminished by successful detection and sinking of large numbers of boats, so that the provision of crews became almost impossible. The last U-boat to be sunk at the entrance to Scapa Flow was found to have been manned entirely by naval officers who had volunteered for a service which ordinary seamen looked upon as involving certain destruction.

When the German mercantile navy was handed over to the Allies, the amount of the world's shipping had somewhat diminished, but the ocean commerce had diminished in greater proportion. The shipping companies entered into agreements to maintain freights by laying up ships. Building was arrested. At the present moment (December, 1922) the shipbuilding yards of Stettin and Hamburg are filled with ships in course of construction. It can not thus be long before a new German mercantile marine will challenge the Allied lines in all neutral ports as well as in those Allied ports which may be open to them. Freights will then inevitably decline. Great Britain took over the railways on certain terms from the companies and handed them back after the war was over; so did the United States. The German railways had for the most part belonged to the constituent states of the German Empire. When they were taken over by the Imperial Government, that government assumed all obligations attached to them.

The several states were both unable and unwilling to reassume the burden and the railways thus remain in the hands of the Reich.

Demand for Commodities

On the outbreak of war there was a sharp decline in demand for commodities in general consumption. The urgent demand was for ready money, and goods and stocks were sold for what they would fetch. This phase soon passed over. The chief effect of the war was the change in the commodities which were demanded—cloth for uniforms, rifles, guns of large calibre, unheard-of quantities of shot and shell and food for the armies. These were the commodities in urgent, increasing and eventually enormous demand. The greater part of the supply corresponding to the demand it was the task of Great Britain to organize. From the beginning large amounts of ammunition were manufactured by the United States, Canada and Japan, but the bulk of the supplies of uniforms, arms and munitions for the British Army, as well as a large part of those for the French and Italian armies and even for those of the United States, was supplied by Great Britain. The demand was so urgent that extremely high wages were paid, notwithstanding the fact that the working class was recruited by large numbers of women and by men not of military age who did not belong to the ranks of manual labor. Even so, specially skilled men had to be withdrawn from the trenches in order that those who remained might be supplied with munitions. During the final year of the war the production of military stores was overwhelming.

In order to produce this result, practically every industrial establishment in Great Britain had to be reorganized. This was not the task of the government or its officials; it was the task of the heads of businesses. On the outbreak of the war the British government set aside a large sum of money for the purpose of facilitating the transition of industry from a state of peace to a state of war. This amount was lent to the industrial establishments and repaid by them out of the profits of war contracts. Then, when the war was over, these industries had to be once more reorganized for the purposes of peace after four years of war. The former channels of trade had to be reopened, manufacture of customary products had to be resumed.

What occurred in Great Britain occurred in a more or less similar fashion in all the belligerent countries. New factories for the production of war material were built in Germany and Austria as well as in England, France and the United States.

Demand for the necessaries of life became acute in all the countries affected either by the British blockade or the German

submarine campaign. The former was by far the more effective. It rendered sea-borne traffic to Austria practically impossible and it rendered sea-borne traffic to Germany very difficult, although through Sweden a certain amount of traffic was sustained throughout the war.

The fact that every country in proportion as it was industrialized was compelled to import increasing quantities of food led to the widespread belief that a modern war must be of short duration because no country could long survive a blockade. In this belief, the endurance of mankind under exceptional circumstances was unduly underestimated. In all of the belligerent countries there was shortage of food. The fighting forces of the Allies, with the exception of those of Russia, were throughout well supplied. The fighting forces of Germany and Austria were also well supplied. In all of these countries, however, the civilian population suffered hardship, increasing in gravity as the course of the war lengthened. Certain commodities which have become necessaries of life, such as fats, sugar, etc., were latterly almost unobtainable in Central Europe. In all countries rationing systems were adopted.

Demand for commodities as it existed in 1913 has by no means been resumed. The purchasing power of the people has been diminished (a) in Western and Central Europe by taxation; (b) in Eastern Europe by social revolution; (c) in America by the decline in relative value of agricultural products.

(a) While the purchasing power of the people has been curtailed by increased taxation, the revenue represented by this taxation, in so far as it would have been expended by the people, had they had the disposition of it, in general commodities, has merely been diverted by the state into payments of wages to functionaries who might have competed in the market for labor and contributed to reduction of wages, into purchase of goods other than the normal consumption in goods of the people or into payment by some means of external debt. Thus, the purchasing power of the German people is curtailed by taxation and the revenue derived from that taxation is partly devoted to the payment of the deficit in the German railways arising chiefly from the employment upon these of men who otherwise would compete in the labor market, draw from unemployment funds or receive military or invalidity pensions. The revenue is also partly devoted to the payment of the salaries of numerous probably unnecessary functionaries employed by the state departments for the same reasons. The revenue is also partly devoted to the payment of the Reparations and the costs of the armies of occupation—in other words, on account of external debt.

In England and France the purchasing power of the people is curtailed for substantially similar reasons. In both countries the government administrations are loaded with functionaries beyond the economical point, but this condition is difficult to alter because of the social reactions to which alteration would give rise. In England taxation is relatively high because of the policy of the government, which from the beginning of the war has been to defray the costs of the war with all speed in order that future generations may not be unduly burdened. As in the case of Germany, the external obligations of the British government necessitate the setting aside of a large part of the national income as principal and interest.

So far as concerns the interest upon government obligations held by its own people, the payment of this interest does not involve a reduction in the national resources; it involves merely distribution of these. It does not even involve redistribution, for this interest is payable in respect to capital which has been furnished to the government by its own citizens largely from the proceeds of their foreign investments, from other savings or from private debts incurred by them in anticipation of future savings. In addition to taxation as the most important element in the restriction of spending power, the necessity of saving in order to repay the funds borrowed for investment in government securities, constitutes an additional restriction, closely corresponding in its effect upon the individual to taxation in the form of a levy upon capital. These considerations apply not only to Great Britain, but also to France and Germany.

(b) In Eastern Europe the purchasing power of the people has been affected by social revolution. In Russia the destruction of the class of landed proprietors and of the class of factory owners and merchants, through the confiscation of their property by the Soviet government or by direct action of the workingmen and the peasants, has destroyed the purchasing power of these classes. Since the Russian peasantry had slender purchasing power owing to the self-contained character of their village life, and since the industries of the towns were disorganized partly through the absence of industrial organizers and partly through the absence of demand for their products owing to the elimination of the classes which consumed them, the purchasing power of Russia as a whole has been destroyed. It can not possibly be recovered until the return of the expatriated consumers or the growth of a new consuming class. Meanwhile, there is no effective demand in the towns owing to the disorganization of industry, and there is no effective demand in the villages owing to the decline of agriculture

due to the destruction of the organized means of disposing of its products.

(c) In America the decline in purchasing power has been due chiefly to the decline in the relative value of agricultural products. Since the United States is predominantly an agricultural country, the number of consuming persons who are engaged in agriculture and its ancillary industries is greater than the number of consuming persons otherwise employed and increased industrial wages do not necessarily imply net total increase of purchasing power on the part of the people as a whole.

From these various causes the demand for commodities has declined as compared with the period before the war, and this decline may fairly be held to be one of the reactions of the war.

Movements of Prices

I have noticed the tendency towards the diminution of the purchasing power of gold; otherwise, the advance of prices from about 1886 up till the summer of 1914. On the outbreak of war, there occurred a general collapse of credit, everything was for sale for ready money and prices fell even for those commodities which obviously must within a very short time be urgently demanded for war purposes. So soon as Great Britain began to organize her industrial life on a war basis, wages advanced rapidly and the prices advanced of all commodities destined for employment directly or indirectly in war. In the hurry and bustle of the campaign little attention was paid to economy. Those nations which remained neutral at the outbreak of war reaped enormous gains. Roumania, Italy and the United States, all of which afterwards became belligerents, as well as Sweden, Norway, Spain and Holland, gained by the advance of prices of the goods which they could supply or transport.

The reasons for the advances in prices at this time were chiefly the following:

1. Urgency of demand in the case, *e. g.*, of war material.

2. Difficulty of procuring supplies of raw material owing to the commandeering of shipping and to the war risks.

3. Difficulty of procuring labor, owing to volunteering and later conscription.

4. With every advance of wages necessitated by the difficulty of procuring labor, there came a tendency to spend these wages and thus to enhance the demand for commodities and there also came a tendency to diminish rather than to increase the number of working hours or the activity of labor. Patriotic appeals had frequently to be made in order to counteract this tendency.

5. Enhanced profits obtained by those who organised war industries. These new and quickly earned profits were often spent as quickly by those who were not accustomed to the possession and judicious control of large

means. These luxurious expenditures tended to increase prices of certain commodities.

All of these causes affected all countries whether belligerent or not. The last-mentioned cause affected especially neutral countries like Spain, for instance. In that country the profits arising from supplying Spanish products to the belligerents, especially after the competition of Italy was eliminated upon her entry into the war, were so great that demand arose for many commodities not previously used in Spain. In 1917-18 the Spanish dealers practically cleared out the fur market and contributed to an advance in the price of furs all over the world.

Efforts were made by means of emergency legislation to counteract these causes for the advance of prices. Food and fuel control boards were established and people were prosecuted for purchasing more than was necessary for their use.

In those cases where the legislation was supported by public opinion the checking of demand probably would, taken by itself, have conduced to maintenance of a relatively low level of price; but the check to supply which the legislation inevitably involved probably more than counteracted its influence in keeping down prices. The British government was forced into the position of organizing supplies. This it did by establishing a purchasing agency in New York by means of which to a large extent it controlled the price of wheat, for example, not only for Great Britain but for the United States as well. This action probably on the whole succeeded in maintaining a more uniform price, although not necessarily at all times a lower price than might have been arrived at in a market without restrictions.

In Germany and Austria food control was established during the war and this control remains, although in a modified form. The terms of peace, which limited the territory of the new state of German Austria, gave to Czechoslovakia a large industrial district and the patronage of the latter new state by the Entente Powers has enabled it to establish itself to advantage Whether or not the people can develop political and economical sagacity, qualities which their previous absorption in the Austrian Empire did not permit them to exhibit, remains to be seen. For some time after the erection of the new state, the new rulers seemed determined to make it wholly self-contained. They, therefore, refused to trade with their neighbors, either by practically prohibitive tariffs or total prohibition. Thus they placed so high an export duty upon sugar that Austria imported from Java instead of buying it within twenty miles of Vienna, as might have been done otherwise. The Czechoslovakian policy was found to be im-

practicable, and some months ago trading relations were established between the new state and the surrounding countries.

Currency Systems

I have pointed out that in June, 1914, the currency systems of Europe were on a stable foundation. There had been at times during the previous half century inflation of prices as between 1870 and 1873, but there was no currency inflation. Large gold reserves had been accumulated, the credit of the governments of all of the powers was firmly established, chronically bankrupt countries like Turkey being left out of account. Immediately upon the outbreak of war the credit of all governments declined. The expenses of a general war were inevitably to be enormous and the outcome of it uncertain. Governments must come into the money markets as borrowers and therefore the security of previous issues diminished. Prices of the funded debt of all countries declined. In war immediate funds are necessary. The most immediate source of government funds is the printing press, by means of which government promises to pay may be issued rapidly. Where a government already issues notes, increase in the number of these may be effected for a time without attracting attention and therefore without affecting the credit of the government. Where the government has no notes in circulation, as was the case in Great Britain, a government issue may be made, the extent to which it will be received without affecting the credit of the government depending upon the confidence of the people in the stability of the government. Such notes do not usually avail for foreign payments. Germany, France and Great Britain quickly availed themselves of the immediate resources of the printing press. In all of these countries prices were—with, we may allow, at least partial success—controlled; therefore for a time the purchasing power of the new paper money, inadequately secured as it was by gold reserves, was maintained; but after these issues had reached a certain amount the purchasing power not only of the new issues but of all government notes in circulation declined. Not only did the notes of the various governments decline in purchasing power, but the notes of all the banks, even although these were not government banks, declined in purchasing power also, even although the notes of these banks were amply secured by gold reserves in their possession, owing partly to the reluctance of the public to submit to the inconvenience of having to deal with two prices—one in government currency at a low level of purchasing power and the other privately issued currency at a relatively high level. All notes also declined, because it was evidently within the power of the respective governments to place an embargo upon the emission of gold by the banks.

During the war the issue of paper money was kept fairly well under control, through the control over prices, especially in Germany. Yet the value of the paper money of all countries in terms of gold began to shrink before the close of the war. So far as the German mark or the Austrian krone was concerned, there being no trade between the great commercial countries and Central Europe, the external exchange value of the currency of neither of these countries could not be determined. Determination could only be arrived at when foreign transactions began to take place. Anticipation of such transactions began immediately on the close of the war and the first actual transactions showed that the external world had placed a relatively low value upon Central European currency. Meanwhile Germany and Austria alike had had to disburse gold. With every reduction of the reserve, sound theory determined that the proportionate amount of paper money issued on the strength of the reserve should be withdrawn. In grave emergency expediency generally takes the place of sound theory, and this was not done. Within two years after the outbreak of war, notwithstanding commandeering of gold in various forms, the German government was compelled, in order to obtain necessary raw materials, to draw upon its reserves. It happened that, when France paid the indemnity to Germany in 1871-73, a portion of the gold with which a part of the indemnity was paid was purchased from England. This gold had a unique mark, for it was coined in 1871 and the whole of the gold coinage of that year was remitted to Germany on behalf of France. These British sovereigns were placed in the Fortress of Spandau, as a war hoard, and not a single example of the British coinage of that year was to be seen in circulation or in the possession of the banks. In the autumn of 1916 coins of 1871 began to make their appearance in London. They had been paid by Germany to Holland, Sweden, Spain or Switzerland for supplies furnished by these countries, and through these channels had found their way to England.

Germany thus lost her grip on her currency system during the war. She undoubtedly hoped to recover it after the war was over, but the collapse of German government credit has prevented her from doing so up till the present time. In addition to the extraordinary issues of paper currency during the war, by means of which Germany raised a continuously accruing forced loan, Germany also issued numerous formal loans. By the end of the war, the financial resources of the German government were exhausted. It appeared to be impracticable to attempt to raise further loans. The only plan which commended itself to the German government

was to encourage to the fullest extent the resumption of industry and foreign commerce, and by this means to secure a basis upon which an edifice of taxation or a policy of domestic borrowing could be built. Two means were adopted towards this end: By Article 165 of the new constitution of the German Reich, a body was instituted to be known as the Federal Economic Council. This council was affiliated with a federal workmen's council and this again with local workmen's councils. Some writers have seen in this system an institution rivaling that of the political government and destined to replace it in the direction of the national affairs. Excepting for the presence in the Federal Economic Council of employers, the system is not in essence dissimilar to the Soviet or council system of Russia. It appears to me that the view of these writers is exaggerated. The functions of the economic council, as set forth in the Constitution of the Reich, are strictly limited and unless the council usurped the powers of the Reichstag, which it could only do by means of a revolution, there does not appear any likelihood of its actually governing Germany. If it did so, its economic functions would certainly be neglected for the political functions it assumed. Nevertheless, the formation of this economic council is a significant consequence of the war, the defeat and the revolution. It involves at least the possibility of accord between employers and employed and gives the latter a definite place in the councils in which are determined the directions of economic policy. In order to encourage the rehabilitation of industry and commerce, ordinary and so to say negative means, such as protection, were inadequate, and it was necessary to devise positive means. The means that lay most readily to hand were to be found in the normal relations of the German banks to industrial enterprises. Such enterprises had been all along fostered and controlled by the banks to an extent unknown in America. Bank directors devised and organized new enterprises and placed in charge of them persons in whom they had confidence. What was needed was an expansion of this already existing mechanism. But the banks had been obliged to place their resources in the hands of the government, and these resources had been utilized by the government in the prosecution of the war. German private capital had been largely absorbed into government loans. The government was unable or it was presumed to be unable to raise new loans; the banks could obtain from an impoverished people no fresh resources. How could the industries be financed until they began to make returns? The method adopted was in effect for the government to print mark obligations and to deposit these to its credit with the banks. The banks could then furnish the credit they

thought expedient to the industrial and commercial concerns already on their books. If the process could be carried on with due restraint, there was at least a possibility that the profits of industry would eventually justify it. If some such expedient were not adopted, German industry might not recover for a generation, or it might not recover at all. The foreign channels of trade which Germans had opened up in past years would be used by others. Germany would become predominantly an agricultural country, and the comparatively sterile character of most of her land would prevent her from maintaining even her existing population, while growth would be impossible.

Thus the printing press was set to work. A paper money policy is like the slide of a toboggan—progress is slow at the top and it gradually becomes accelerated. If the toboggan meets with an obstruction, or if it diverges from the straight path into the ditch the consequences may be fatal. If, however, the descent becomes less steep and the vehicle glides smoothly on to the plain at the foot of the hill all is well.

A paper money policy may have any of these issues. Like the toboggan it may land its people in the ditch or it may stop of its own accord smoothly and without material damage to any one.

Germany had before her a choice of evils. In any case, her position was a hard one. By that I do not mean that she is entitled to sympathy. She elected to go to war, she sacrificed everything in the course of the war and in the end she was defeated and destitute; but she made others destitute and had indeed seriously diminished the power of her victorious enemies to assist her to rise again, even if they were generous enough to desire to do so. Some German economists object to the financial policy of the government on the ground that it threw upon the mark the whole weight of national reconstruction and that this reconstruction might have been accomplished without imposing a strain on the mark which it could not possibly sustain. None of these critics have advanced, however, so far as I am aware, any practical means which the German government could have adopted to save the mark and to rehabilitate industry. It may turn out that they have not rehabilitated industry permanently, although they have sacrificed the mark. Yet it must be allowed that Germany has been working at the highest pitch which contemporary conditions rendered possible during the past four years. Some other plan might have done the same thing and done it better without any collapse at the end; but no such plan was forthcoming four years ago nor is any such plan really forthcoming now.

Austria did not adopt the same policy as Germany. She

adopted the policy of drift. She paid out her gold and issued paper as required. Her currency system went to pieces as her political system had gone. Yet so paradoxical has life become that in some ways Austria is better off than Germany, for her rural industries are conducted with a minimum of capital, and Vienna is still an important financial center, although every second person who is to be met in the streets of Vienna seems to be dealing in exchange.

Czechoslovakia and Hungary are better off—one because she has industries and financial assistance for them from the Entente, especially from France, and Hungary because she has the rich plains of the valley of the Danube left to her, with fertile farms and enormous herds of cattle. Both of these countries are in the throes not of inflation but of deflation. For deflation has also its difficulties. Rise of paper prices, in consequence of excessive issues of paper, has as one of its results danger of a sudden check. The Hungarian krone was coming back to par too quickly. Its progress had to be checked. So also was the Czechoslovakian krone rising too rapidly. Wages and prices alike were affected, and measures had to be taken to relax the speed of recovery. In these countries, the approach to normal conditions may confidently be anticipated.

The gold situation at the present time may be described as follows: The total amount of gold in the bank and government reserves of the world is approximately twice the amount in the reserves in 1913. Russia has parted with practically all of the huge stock of gold she held at that time. The absence of credit has compelled the Soviet government to send the gold abroad, and the absence of organized production has prevented it from getting any of it back again. Austria has parted with practically all of her gold. Germany has nearly as much gold as she had in 1913. The following countries have greatly increased their gold reserves: Netherlands, France, Switzerland, Spain, Great Britain, Sweden, Norway, Denmark, Roumania, Japan, Australia and the United States.

The normal flow of gold from one country to another has been impeded by legislation adopted during the war and lasting beyond its duration, by the absence of active demand for commodities, by the absence of important transference of capital from one country to another for investment, by the decline of credit owing to the effects of the war and of the peace upon many national finances.

Stabilization of the presently unstable currencies, like those of Germany, must take place at some period, either by means of a legislative act, written in appropriate terms and passed at an ap-

propriate time, or by the mere refusal on the part of everyone to accept the depreciated mark. In the latter event currencies of all kinds will make their appearance in Germany, probably including metallic pieces that have long passed out of circulation. Ancient hoards will be drawn upon and foreign currency will be used extensively. Already a very large amount of one pound notes of the British Treasury, known as Bradbury's, circulate freely in Central Europe and appear in the reserves of bankers. So also do Dutch guilders and, I believe, though to a less extent, United States dollars and Swiss francs.

When the threatened crisis comes in Germany there must be a disturbance of industry and of the export trade, but the essence of the crisis must be in the currency situation.

Wages and Conditions of Labor

Depreciation in the value of gold which we have found expressing itself in the rise of the prices of commodities not merely during the war but for thirty years before the outbreak of war expressed itself also in the rise of nominal wages. There is, of course, no such thing as a universal or immediate rise either in prices or in wages. Advances in either proceed invariably gradually, although the steps may be irregular. An important advance in prices of the necessaries of life must have as consequence either the advance of wages of the whole group of laborers affected or the diminution in the numbers of that group until the wages of the remainder advance because of the scarcity of labor. Wages, however, depend primarily not upon the cost of the necessaries of life, but upon the net return to the product of the labor for which the wages are paid. An author, for example, receives the market value of the product of his pen, which value may not only be below his own estimate of the worth of that product but may be quite inadequate to procure for him the means of life while he is devoting himself to writing. The persons who purchase his writings are not concerned in the least whether he makes a living wage out of them or not or even whether he lives or dies. There is no necessary author, nor is there any necessary laborer or necessary individual man. Yet, if writing did not on the whole yield a reasonable return and if laboring on the whole did not do so, there would be neither writers nor laborers. Advances in wages have not occurred because the prices of the necessaries of life have risen, although the advance of these is often made the ground of a demand for the advance of wages; but they have occurred because the rise in price of the product of the labor in question has enabled the organizer of labor to accede to a demand for increased wages

or to anticipate such a demand. This condition does not depend upon the employing system but must exist in any system which involves the payment of wages for work done—as, for example, municipal or state employment.

Wages have thus risen in those industries in which the price of the product has risen, and the price of the product has risen because of the increased urgency of demand for it. There are always two persons in the making of a bargain, and it is, therefore, impossible for one of these persons to determine the price; but if the seller is urgent, if he must sell, the price which is fixed upon will be near the price which he would take rather than not sell at all, whereas if the buyer is urgent the price will be near that which he would pay rather than forego the purchase. The buyer's price and the seller's price are each determined by the urgency or otherwise of their need.

When the nations were organizing themselves for war, they were extremely urgent buyers—the prices were a secondary consideration. What they wanted were munitions. While the customary scales of prices and wages were upset, the fundamental principles of economic transactions were not otherwise than exemplified.

Many of the second rate newspapers spoke of the laws of political economy being upset by the war, and of the "doctrine of demand and supply" being in abeyance. After that it was only a slight step, which some of them made, to the statement that the war had altered the laws of nature.

These are absurdities. The nations during the war were most urgent buyers, and they had to pay the extraordinary prices that even in time of peace the unusually urgent buyer has to pay. The war did illustrate this fact, however, *viz.*, that what is important is the supply of goods at the place and when they are wanted, not the pecuniary price that is paid for them. Even if debt has to be incurred in respect to that pecuniary price, by the time the debt comes to be paid, who can estimate whether the pressure of that debt will be more than equivalent to the value of the life that is saved by the presence of the goods here and now?

The demand for munitions and the demand for labor to produce them, together with the scarcity of labor in consequence of that demand supervening upon the demand for troops, impelled many of those who had the task of organizing war industries to improve the conditions under which labor was carried on. Many factories were built, for example, specially designed for the labor of women, with comfort of which pre-war factories were destitute. So also in the case of factories in general, more attention was paid to the convenience of the worker than ever before. The demands

of the War Offices were candidly explained to the employes and in regard to many war contracts the profit of the employer was well known. There was no fluctuation of employment. It was a hard and steady grind—day shifts and night shifts alternating. The heads of the enterprises no longer found their time divided between factory management and devising means whereby they might obtain orders to keep their factories working; the orders came to them unasked, they had only to execute them with all speed.

The war thus transformed industry and regularized it. The consequence was unprecedented output. By the end of the war factories in every one of the belligerent countries were producing munitions with a speed which would have been regarded as miraculous at the beginning of the war.

Probably some of this speeding up of industry might have remained after the war, and might under adequate direction have influenced the conditions of the peace; but the transition from war to peace would in any case have interrupted the regularity of the system and would have involved a material change in the motive for such unremitting energy. No pecuniary motive would have sufficed.

After the war, even the munition makers—in all countries, even those which were the least war weary—were rejoiced that it was no longer necessary to work at the top of their speed.

Labor Movements

During the war labor movements in all countries subsided. Internationalist labor propaganda, beginning in 1849, which had some influence in 1862 and again especially in Great Britain in 1884, had not affected the political situation in 1870, nor did it do so in 1914. The French Socialists put France in the first and socialism in the second place, the German Socialists were Germans first and Socialists afterwards. Difference of race, of temperament and of economical conditions made international labor movements practically impossible. Even national labor movements were ignored in the presence of international conflict. So soon as the war was over, the leading socialists were prepared to take advantage of the political situation and to utilize the rich material for agitation offered by the disorders, discontent and miseries which the war had left in the defeated countries and especially in Germany, Austria and Russia. In Russia, the Czarist government was overthrown by a combination of parties of which the Constitutional Democrats were the most influential. The government formed by this combination was succeeded by the Dictatorship of Kerensky, and this was succeeded by the Soviet or Labor government. The Soviet government was composed not of genuine repre-

sentatives of the Proletariat but of Social Democrats who had adhered to the fraction of their group led by Lenin. They immediately declared war against socialists of all other parties as well as against the property owning classes. Hundreds of thousands of these were killed and the government of Lenin established itself. Then began a great experiment. Lenin attempted to build a communist society composed of about a hundred and forty millions of people, the populations of Finland, Poland and the Baltic Provinces having broken away from Soviet Russia. This experiment—by far the largest communist experiment ever attempted—immediately met with great difficulties. The peasantry opposed it either with active hostility or sullen acquiescence in what appeared to be inevitable. The industrial proletariat in the towns melted away into the villages from which they had come. Industry was disorganized partly through the absence of workers and partly through the destruction of the class of industrial organizers. Under these circumstances transportation broke down, exchange of commodities, a necessary postulate of a communist or any other system was at an end. Peasant agriculture declined and famine supervened. The Soviet government changed its policy in 1921 after four years of fruitless effort to establish communism and began to seek the assistance of capitalists and capitalist organizers of industry. Progress toward economic recovery has been slow, but there are signs that it is proceeding. Among the economic reactions of the war this Russian experiment must take an important place in history, alike for its positive effect upon Russia and for its negative effect upon all other countries. The impossibility of establishing communism at a stroke has been fully demonstrated.

The effect of the demonstration upon the labor movement in all countries has been salutary. In every country there were extremists who advocated views similar to those of Lenin, and they have either been converted—like Mussolini in Italy—or have been convinced that "the way of order though it leads through windings is the best."

Among social reactions of the war must be counted the revival of efforts to establish councils or boards by means of which employers and employed might discuss their mutual or their divergent interests. The Whitley Councils in Great Britain and the Federal Economic Council with its subsidiary councils in Germany are examples of a tendency towards recognition of the interest of workingmen in the continuity of production.

The economic bearing of the counter revolution, or anti-labor movement, represented by the Fascisti in Italy and the Technical Emergency Force in Germany—both originating in volunteer groups organized to break strikes and to prevent proletarian domi-

nation—must be recognized. Such movements are a very natural counter-active to aggressive labor movements, and their members may be presumed to have the advantage over the latter of superior education. In Germany the technicians seem to be separating themselves from the Socialist ranks. Since they formed the most energetic and reliable elements in these ranks, their growth may be quite disastrous to the German Socialist groups.

Movements of Capital

The war arrested movement of capital excepting under governmental control. Immediately after the Armistice, movements of capital were resumed. Exact statistics are wanting, but it is known that large amounts of foreign capital have been invested in Germany during the past three years. The investment of this capital has undoubtedly rendered more complicated the question of Reparations; because a capital levy upon these investments, in order to yield funds to pay Reparations, would be looked upon naturally as a breach of faith and would intensify the ill feeling which already exists against Germany abroad. Otherwise, the conditions already described as existing in nearly all countries have militated against the movements of capital from one country to the other. In so far as reparations have been paid by Germany, they have been effected by means of the export of capital, there having been no other fund from which to draw the payments.

Mobility of Property in Land

The pressure of taxation and the advance in wages for service have together conduced to an unprecedented mobility of property in land, especially in Great Britain. Estates have been broken up, country houses have changed hands; those who succeeded in acquiring fortunes during the war have purchased them or they have been converted into schools and other public institutions. Lands of corresponding character with regard to proximity to centers of population are more easily acquired and are acquired at lower prices in Great Britain than in the United States. This condition exists to a certain degree in France and Germany. The payment for purchased land in Central Europe must, however, be made in foreign currency. No one in Germany or in Austria, for example, will sell for payment in the depreciated currency of these countries. There has thus been somewhat less mobility of land in Germany and Austria than might have been expected. Those sales which have been made have involved foreign purchase or purchase by resident Germans who had command of foreign resources.

Public Opinion Regarding the Limits of the Functions of the State

I have noticed the increase of the function of the state in the period immediately before the war. During the war the state assumed numerous functions with which it had not previously been entrusted in modern times. Where railways had been under private ownership, as in Great Britain and the United States, the governments took them over. Where prices had not been controlled, the governments controlled them. Municipal ordinances were passed, greatly extending the area of municipal authority. Not all but nearly all of these emergency functions have since been removed from the state in spite of a certain amount of protest on the part of those who adhere to the policy of collectivism. The practical experience of the exercise of a policy of nationalization and national control seems to have been on the whole adverse to that policy. The chief alleged faults developed during the extension of nationalization were over-manning of the staffs employed by the state, supineness on the part of the state employes, extravagance in time and material and tendency towards arbitrariness in dealing with the public. These objections may or may not have been universally valid; but they had sunk deeply enough into the public mind for little protest to be made when the United States and Great Britain handed back the railways to their proprietors instead of acquiring them for the state. Canada was placed in a different position. She had not taken over the railways; but two of these fell into financial difficulties during the war, and probably to some extent as direct consequence of the war. The government, instead of going to the financial assistance of these railways, purchased them. Up till the present time the management has not succeeded in paying operating expenses. Whether or not in the future this record will be altered remains to be seen.

Public Indebtedness and Taxation

The indebtedness of all countries—belligerent and neutral—has increased as direct consequence of the war. Yet, owing to the fluctuations of exchange and the steady downward tendency of the exchange of Central European currencies, the gold price of the debt of Germany and Austria, for example, has declined. If these countries were now able to purchase their debts with depreciated paper, they might readily reduce them to an insignificant amount. They are not able to do so because some part of this debt is irredeemable and much of this form of debt never comes into the market, and because the moment the governments began to buy on a large scale, the prices of the obligations would rise and the

amounts of paper money which would have to be issued would increase even more rapidly than they have done.

There has been a tendency in all countries to raise the additional taxation required for interest payments and also for increasing administrative expenses by means of a graduated income tax. Beginning in Holland nearly thirty years ago, the graduated or progressive income tax has become practically universal.

Heavy taxes mean redistribution of wealth. The state takes these from the pockets of some people and puts the revenues in the pockets of others. The taxpayer as taxpayer pays taxes, and the holder of government bonds as such receives his dividends. These are often the same person; but the amounts are not necessarily equivalent. Had the governments not adopted the wise policy of issuing public debt in sums of small denomination, thus inducing large numbers to invest their savings in it, the public debt would have been absorbed by a relatively small number of persons and a class of fundholders would have been created. The consequence of alternative action of this kind must have been movements for the repudiation of government indebtedness. There are no such movements in Western Europe or in America.

While the war has thus exercised an influence in numerous economic fields, and while in some of these the influence has been important, it is essential to attribute to the war and to the peace which followed only those reactions which clearly can be traced to them.

SOCIAL LIFE AMONG THE INSECTS[1]

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LECTURE VI. THE TERMITES, OR "WHITE ANTS." II

SOME of the most extraordinary idiosyncrasies of the termites are exhibited in the construction of their nests, the termitaria These bear a certain albeit superficial resemblance to ant nests, but express very clearly the cryptobiotic tendencies of the termites, their great predilection for darkness, moisture and protection from air-currents. Having shut themselves off as much as possible from the outer world and having therefore become almost or quite blind and very thin-skinned, they would be exterminated by predatory insects, birds and mammals and especially by their most inexorable enemies, the ants, if they had not learned to compensate for their feeble and defenseless condition by building unusually strong and resistant nests. There are, to be sure, a few species, like the African *Hodotermes havilandi* and the Indian *Eutermes monoceros*, which are deeply pigmented or have well-developed eyes and forage in the open sunlight, but these are very exceptional.

The nests of termites are of two kinds, the diffuse and the concentrated. The former are not definitely marked off from the environment in the soil or dead wood and consist merely of excavated galleries. Such nests are made by the Protermitidæ and many Mesotermitidæ, *e. g.*, our common *Reticulitermes flavipes*. The concentrated nests are clearly marked off from the environment and are definite, elaborate structures consisting of a royal chamber for the king and queen in the center, surrounded by more or less concentric and inosculating galleries and chambers and an outer covering often of considerable thickness and solidity.

The concentrated nests differ greatly in form in different species. They consist either of earth or woody material or of both, but these substances are subjected to an elaborate preparation. Both the soil and the wood may be swallowed by the workers and after mixture with secretions either regurgitated or passed through the intestine and used as building material, or particles of soil or wood may be merely bitten off and agglutinated with saliva. On drying the substances employed, especially the saliva-impregnated earth, become almost as hard as cement, so that it is by no

[1] Lowell Lectures.

means easy to break into some of the larger earthen termitaria. Termites may build either in or on the ground or on the trunks or branches of trees. When in the former situations the nests are typically conical mounds, but their size and shape may vary greatly. In all cases they differ from ant-nests in lacking exposed entrances. When the termites do not pass to or from the nest beneath the surface of the soil, they construct earthen or carton arcades or galleries, so that they can visit their feeding grounds without exposing their bodies to the light and air.

The most conspicuous type of termitarium in the Old World tropics is a rounded boss or cone built up very gradually over the original subterranean nest established by the royal couple and their first broods of workers. Termitaria of this description are often so large and numerous that at a distance they resemble a village of native huts. Closer study of these nests reveals the existence of several different types which may be conveniently grouped as the more or less conical, the columnar or tower-shaped, the wedge-shaped and the mushroom-shaped. In the open savannahs of Central Africa a large, broad-based, bluntly pointed, grass-covered termitarium is in some places so common as to make large areas of the soil very uneven (Fig. 104). Even larger, conical masonry nests were described and figured by early explorers like Smeathman. The photographs of a more recent traveler, Mr. H. O. Lang, give a better idea of these structures, which may attain a height of 18 to 20 feet (Fig. 105). In Australia the forms of the earthen nests seem to be even more varied. In New South Wales the structures of *Coptotermes lacteus* first appear above ground as broad, flattened, extremely hard bosses, but they gradually grow up till they form smooth tower-like structures 6 to 10 feet high. The largest of these nests are probably about 10 years old. I infer this from the statements of Machon, who found that similar nests in Paraguay reach a height of 12 feet in 11 years. But there are taller nests in Australia. Those of *Eutermes pyriformis* figured by Saville Kent and Froggatt are veritable skyscrapers 18 to 20 feet high. At Koah, in Northern Queensland, I found another type of columnar nest, also the work of a species of Eutermes but short and bulky, often flattened at the summit and narrowed or constricted at the base. A transition between this and a more conical type is represented by certain termitaria found by Saville Kent in the Kimberley district of Western Australia. In the northern part of the same continent we find the singular wedge-shaped structures, called compass or meridional termitaria, because they are constantly oriented with their two long surfaces facing east and west and their narrow ends facing north and south. The pe-

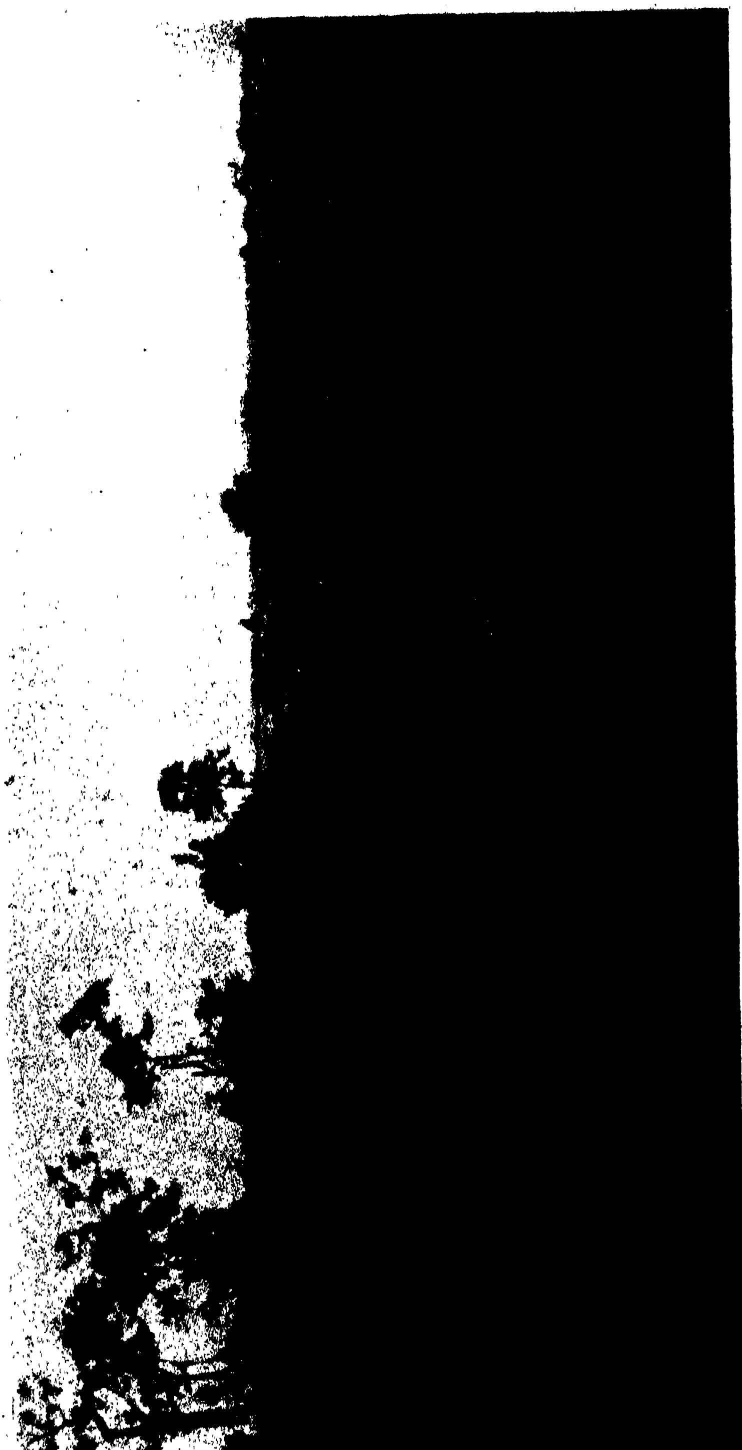


FIG. 104

Mounds of *Termes natalensis* in a grassy plain during the rainy season. Niangara, Belgian Congo. (Photograph by H. O. Lang.)

FIG. 105
Pyramidal termitarium of *Termes* sp. at Kwamouth, Belgian Congo. (Photograph by H. O. Lang.)

culiar mushroom-shaped termitaria are known only from equatorial Africa. They are only a few inches to a foot in height (Figs. 106 and 107).

The tree nests, which seem to be more abundant in the American than in the Old World tropics, are usually subspherical or ellipsoidal and vary from the size of a football to that of a barrel. They are black or dark brown, consist of digested wood and resemble the carton nests of arboreal ants (Crematogaster, Azteca), except that they have a royal chamber in the center and lack the entrance holes in the covering, or envelope. Certain African and Indian tree termitaria are more cylindrical and resemble stalagtites or masses of some viscous substance which has been applied to the treetrunk and has congealed on beginning to drip. In one interesting African species we find on the bark of the tree above a

nest of this type a series of chevron-shaped ridges which seem to be constructed by the termites for the purpose of leading the water that flows down the trunk during heavy shower away from the nest (Fig. 108). In British Guiana Mr. Alfred Emerson called my attention to similarly protected nests constructed by an undescribed species of Hamitermes.

Some termites habitually store food substances in the chambers of their nests. Andrews has shown that the common arboreal *Eutermes pilifrons* of the West Indies keeps its food in the form of large solid, lenticular or conchoidal masses in the center of the nest. Some of the African species of Hodotermes (*H. havilandi*) carry in grass, both green and dead, in pieces about two inches long, and the Indian *Eutermes monoceros* collects and probably stores particles of lichens. The Queensland Eutermes that makes the peculiar bulky nests to which I have referred store their many

FIG. 106
Mushroom-shaped termitarium of *Eutermes fungifaber*. Medja, Belgian Congo. (Photograph by H. O. Lang.)

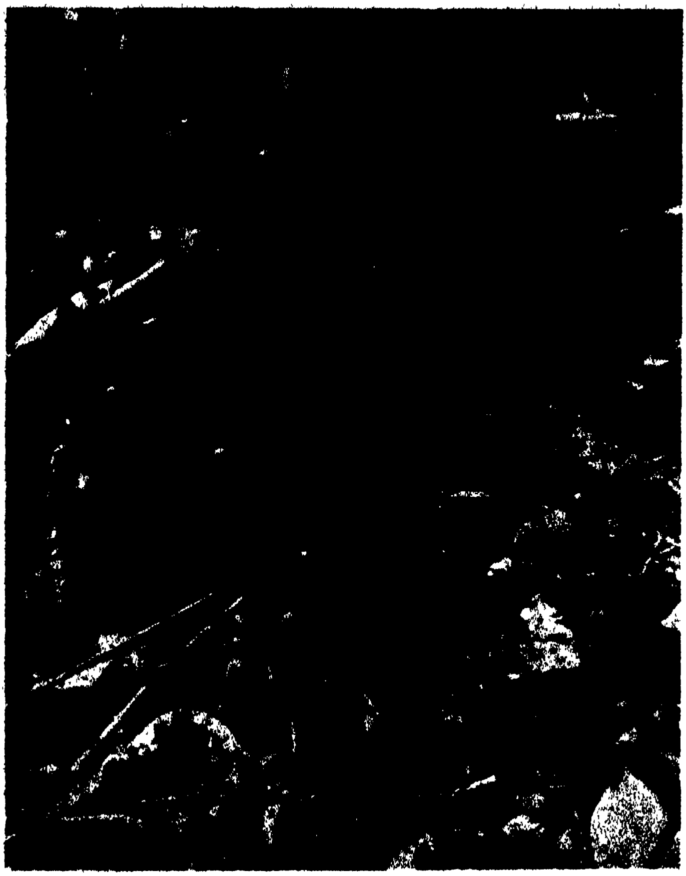


FIG. 107
Section of same nest as shown in Fig. 106. (Photograph by H. O. Lang.)

chambers with great quantities of cut grass. Silvestri has encountered plant-storing termites in South America.

Of the many analogies between the ants and termites the most astonishing is that of the fungus-growing habit. Although Koenig and Smeathman, during the latter part of the eighteenth century, independently and almost simultaneously discovered the termite fungus gardens, their true significance has been appreciated only during the past 30 years, as a result of the investigations of Haviland, Holtermann, Sjoestedt, Petch, Doflein, Escherich and Bugnon. While the fungus-growing ants, as stated in a previous lecture, are all confined to a single Myrmicine tribe, the Attiini, and are exclusively American, the fungus-growing termites all belong to a few genera (Termes, Odontotermes, Microtermes, Acanthotermes, Synacanthotermes, Protermes, Sphærotermes) and are confined to the Ethiopian and Indomalayan regions. The fungus-

growers, in fact, represent the most highly specialized members of the order Isoptera and are the ones that make the huge nests of which I have cited several examples. In section the nests are seen to contain a number of large, spherical or subspherical chambers surrounding the royal cell and connected with it and with one another by galleries. In each chamber there are one or more fungus gardens—sponge-like bodies varying in size from that of a walnut to that of a cocoanut, and resembling the gardens of the Attiine ants, but more solidly and more artistically constructed (Fig. 109). They consist of vegetable material which has been collected and comminuted by the workers, passed through their intestines and built up in such a manner as to present the maximum exposure of surface for the growth of the fungi. Petch, who has studied the fungi cultivated by *Odontotermes redemanni* and *obscuriceps* in Ceylon, describes them as growing on the sub-

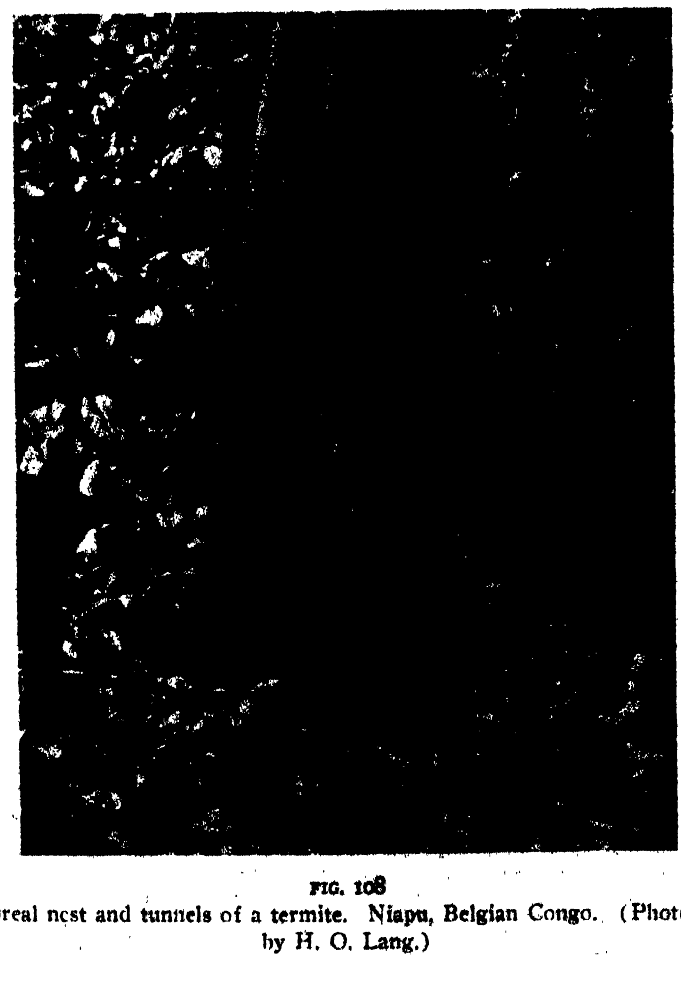


FIG. 108
Arboreal nest and tunnels of a termite. Niapu, Belgian Congo. (Photograph by H. O. Lang.)

FIG. 109

Mushroom gardens of *Acanthotermes militaris* from a nest at Malela, Belgian Congo. The white dots are the food bodies. (Photograph by H. O. Lang.)

stratum in the form of a mycelium studded with little clusters of swellings like the food-bodies in the gardens of the Attiini. He has succeeded in growing the fungi in the absence of the termites and finds that they belong to at least two species of mushrooms, *Volvaria eurhiza* (Fig. 110) and *Xyglaria nigripes*. According to Bugnion, the mycelium is sown automatically by the worker termites, since they feed on fungus-infected wood and the conidia pass through their bodies without injury. The fungus-gardens are really the nurseries of the termitarium and are full of just-hatched young, which crop the food-bodies like so many little snow-white sheep. Neither the workers nor the soldiers feed on the fungus, but the king and queen and the other reproductive forms receive the same food as the young.

FIG. 110
Mushroom (*Collybia albuminosa* = *Volvaria* (*Armillaria*) *eurhiza*) growing from an abandoned comb of *Odontotermes* sp. at Coimbatore, India. (Original photograph by W. McRae, reproduced by T. B. Fletcher.)

The nests of some fungus-growing termites are provided with chimney-like structures, communicating with large tubular cavities which have been interpreted by Escherich as a system of ventilating shafts. This interpretation seems to be supported by the existence of somewhat similar arrangements in the nests of the large fungus-growing ants of the genus Atta, and the probability that the successful cultivation of fungi in subterranean chambers depends on a careful regulation of temperature and humidity. Both Petch and Escherich have shown that the diurnal temperature in the termitarium varies only some 9 degrees though the outside temperature may vary as much as 20 degrees or more. On the other hand, the nests of many fungus-growing termites have neither chimneys nor shafts. Trägaordh and Holmgren therefore regard them primarily as passages for the transportation of materials while the nest is being constructed.

Turning now to the association of termites with alien insects we find another striking parallelism with the conditions in the ants described in my last lecture, but again with significant differences. In the tropics termites are very often found nesting in the walls or even in appropriated galleries of nests constructed and inhabited by other species of termites. Holmgren records as many as eight species thus living in the same termitarium. Moreover, many ants, like the species of Carebara, may also live in termitaria. Escherich cites a number of Indian ants as occurring only in such situations, and in Queensland I found fully a dozen species that seemed regularly to inhabit the nests of *Coptotermes lacteus* and allied termites. Certain termites, too, seem to occur only in the nests of certain other termites, *e. g.*, *Anoplotermes fumosus* of Southern Texas and Northern Mexico, according to Snyder, and *Eutermes microsoma,* which has similar habits in South America, according to Holmgren. Silvestri found that the South American *Microtermes fur* always usurps part of the nest and steals the stored food of *Eutermes cyphergaster*. In India Escherich found species of four genera (Leucotermes, Eutermes, Eurytermes and Hamitermes) living in the nests of the fungus-growing species of Odontotermes. With these same termites occur also two species of Microtermes (*globicola* and *obesi*) which form small fungus gardens in their own galleries, though they steal both the fungus and the materials for the substratum from their larger neighbors. In all these cases, whether of termites associated with other termites or of termites associated with ants, we are dealing only with compound nests. The various species always occupy separate galleries and are usually hostile when brought together. No instances of

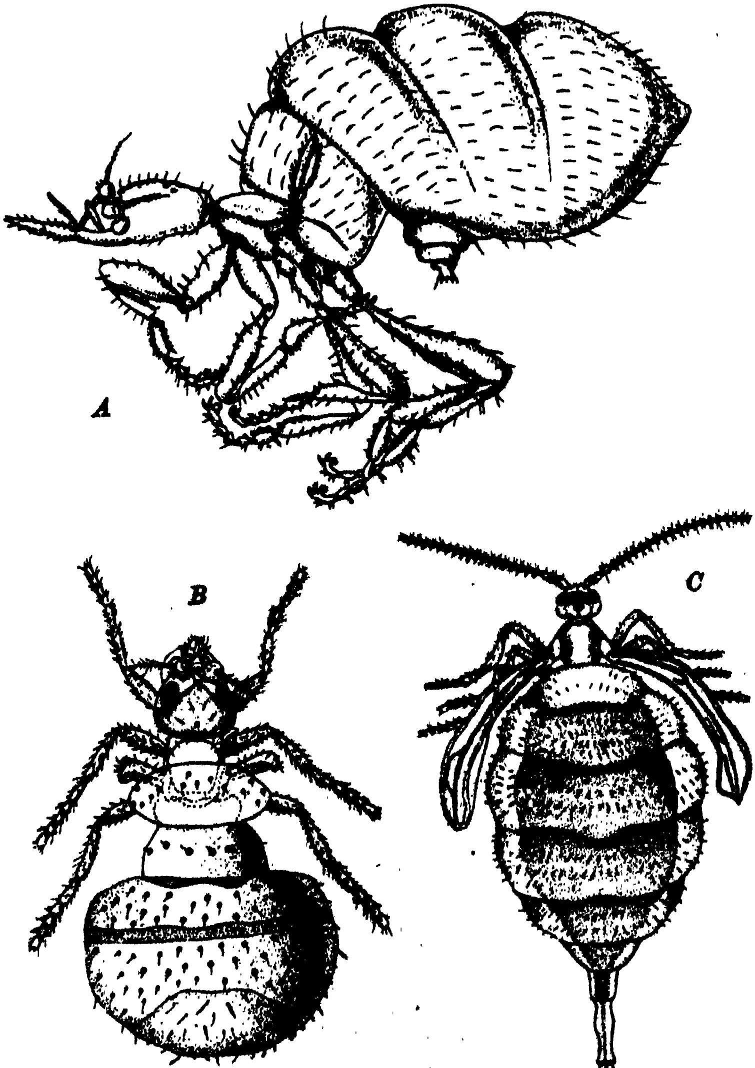


FIG. III

Physogastric termitophilous flies. *A. Termitoxenia heimi*, a Phorid from the nest of the Indian *Termes obesus*. (After E. Wasmann.) *B. Ptochomyia afra*, a Phorid from the nests of the West African *Ancistrotermes crucifer*. (After F. Silvestri.) *C. Termitomastus leptoproctus*, a Nematoceran fly from the nests of *Anoplotermes reconditus* in Southern Brazil and Argentina. (After F. Silvestri.)

mixed colonies, analogous to those occurring among the ants, have as yet been detected among termites.

More interesting are the relations of the termites to the various insects that live in their nests, the termitophiles, of which several hundred species have been described. They belong to the most diverse orders and families and their association with the termites has evidently been brought about by conditions very similar to those that have induced the myrmecophiles to live with the ants. The termitophiles may also be classified in the same manner, as predators, indifferently tolerated guests (synoeketes), true guests (symphiles) and parasites. Some of the forms seem to have undergone little or no modification as a result of their association with the termites, but many of the true guests and a few of the predators have acquired peculiar characters, the most characteristic of which

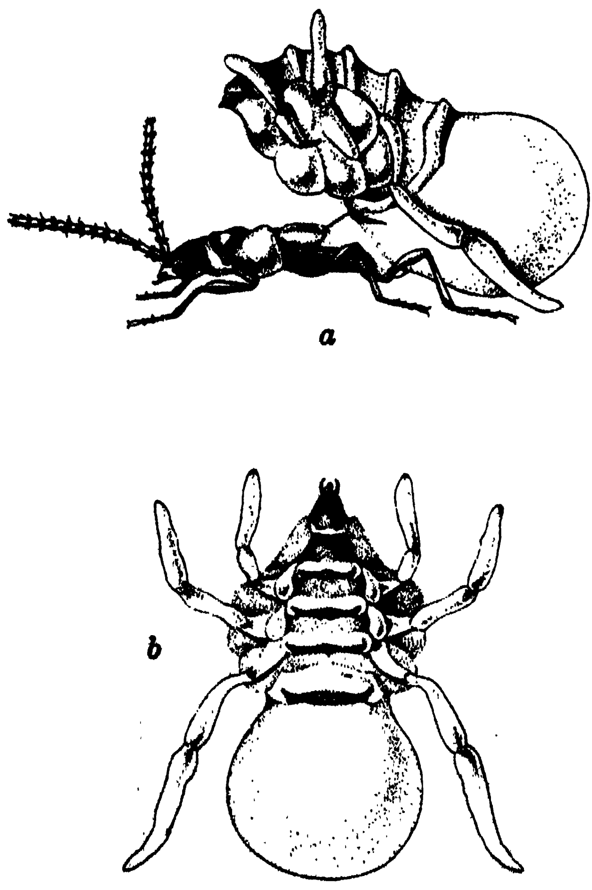


FIG. 112

Spirachtha eurymedusa, a termitophilous Staphylinid beetle from South America; *a*, lateral view of the whole insect; *b*, dorsal view of abdomen, showing the three pairs of appendage-like exudatoria. (After J. C. Schiödte.)

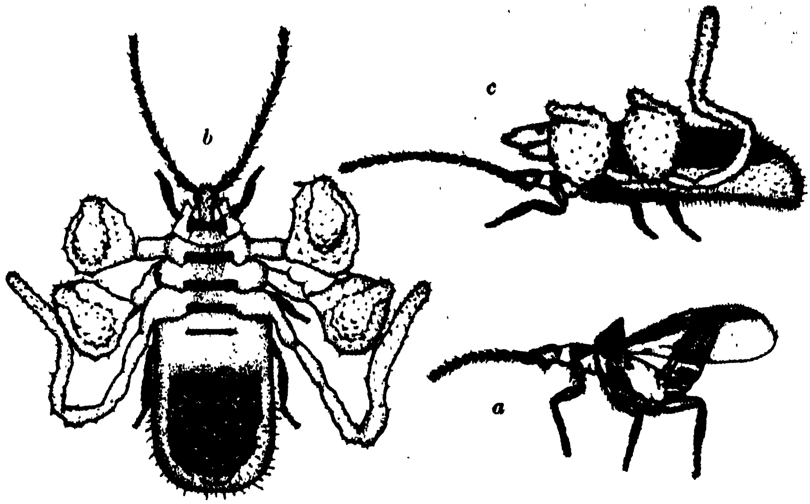


FIG. 113

Termitophilous Staphylinid beetles from the nests of *Nasutitermes (Constrictotermes) cavifrons* in British Guiana. *a, Spirachtha schioedtei* Mann (ms), recently emerged beetle in profile; *b, Spirachtha mirabilis* Mann (ms), physogastric form with three pairs of abdominal exudatoria homologous with those of Fig. 112; *c*, same in profile. Probably *a* is the young adult of *b*, though the antennæ differ. (From drawings by Alfred Emerson.)

is physogastry, or excessive enlargement of the abdomen. This may be due to a great increase in the volume of the reproductive organs or of the alimentary canal but in its most typical form it is brought about by hypertrophy of the fat-body. In correlation with the abdominal enlargement there is a decrease in the size of the head and thorax and a reduction or loss of the eyes and wings. In certain species the body may be furnished with segmental, finger-shaped exudate organs, which are occasionally developed even in physogastric forms. I select for illustration a few of the more striking symphiles and predators:

1. A number of small two-winged flies belonging to the family Phoridæ and the genera Termitoxenia (Fig. 111*A*), Termitomyia and Ptochomyia (Fig. 111*B*), which live in the nests of African and Indian termites, show an excessive physogastry, with the accompanying diminution of the head, thorax, eyes and wings. The wings, in fact, are reduced to small strap- or hook-shaped vestiges. Wasmann, who first described the species of Termitoxenia and Termitomyia, is of the opinion that they are hermaphroditic and viviparous, but Silvestri has recently shown that this is certainly not the case with the closely allied Ptochomyia. He has also discovered in the nest of a South American termite (*Anoplotermes reconditus*) another physogastric fly, *Termitomastus leptoproctus* (Fig. 111*C*), belonging to an entirely different fam-

ily (Termitomastidæ). It shows a similar physogastry and reduction in the size of the head and thorax, but the eyes and wings have suffered less diminution.

2. Physogastry of various degrees is also exhibited by many beetles of the family Staphylinidæ and subfamily Aleocharinæ, which are fed and licked by the termites. The most extraordinary forms belong to the genera Corotoca and Spirachtha, established many years ago by Schioedte for three South American termitophiles. In all of them the abdomen is enlarged to form a huge, subspherical mass, which is turned upward and forward over the head and thorax and in Spirachtha bears three pairs of peculiar finger-shaped exudatoria (Fig. 112). When the insect is viewed from above (Fig. 112*b*) only the inverted ventral surface of the abdomen and its appendages are visible. During the summer of 1920 Mr. Alfred Emerson discovered in British Guiana a still more remarkable species of Spirachtha (Fig. 113 *b* and *c*), which has the two anterior pairs of exudatoria greatly swollen at their tips and the posterior pair elongated and lyriform. The strangest fact about this beetle seems to be that when it emerges from the pupa it looks like an ordinary Staphylinid (Fig. 113*a*) but gradually acquires both physogastry and exudatoria during its imaginal life among the termites. Probably this is also the case with other physogastric termitophiles.

3. The larvæ of certain African and Indian beetles of the Carabid genera Glyptus and Orthogonius, which devour the termites among which they live, show a distinct but less pronounced enlargement of the abdomen.

4. The larvæ of several beetles (Staphylinidæ, Cantharidæ), flies (Anthomyidæ) and moths (Tineidæ), which can scarcely be called physogastric, though the abdomen is well-developed, have, like the adult Spirachtha above described, paired finger-shaped and sometimes jointed exudatoria on the abdominal or even on the more anterior segments. Good examples are the larvæ of the Staphylinids *Paracorotoca akermanni*, described by Warren and *Oedoprosoma mirandum* Silvestri, the larva of the Anthomyid *Epiplastocerus mirandus* Silvestri and of the Tineid moths *Plastopolypus integer* and *divisus* described by Trägaordh and Silvestri.

You will observe that the physogastric termitophiles just described resemble their termite hosts and especially the old queens. They also resemble certain ant-larvæ and the queens of Doryline ants. It would seem therefore that all these convergent cases of abdominal enlargement and accumulation of fat, diminution of head and thorax, blindness and aptery must be the results of living in the same peculiar environment. And we should not be far

wrong in maintaining that the factors responsible for such modifications are confinement within narrow galleries and chambers, a very limited supply of oxygen, absence of light and an abundance of carbohydrate food. We have long known that lack of exercise and plenty of food predispose both man and his domestic animals to obesity. That darkness also favors deposition of fat in domestic animals is shown by the experiments of Ottramare, and we have all heard of the fattening of the geese in the cellars of Strassburg and of the fat-bird (Steatornis) that lives in the caves of Trinidad. Absence of oxygen, moreover, as Dewitz, Bohn and Drzwina have demonstrated, inhibits the development of wings in insects. Andrews says that "the respiratory needs of termites must be slight, since the estimated amount of air in a nest (of the Jamaican *Eutermes pilifrons*) weighing 40 pounds or occupying 4 cubic feet was only 9 volumes for each volume of termite." Whether the partial blindness of many physogastric forms is due to absence of oxygen, as Loeb has suggested in the case of the cave animals, or to the absence of light, as has been universally assumed, can not be decided because both conditions obtain in the nests of termites. Of course, the diminution of the eyes and wings may partially account for the reduction in the size of the head and thorax.

Now the obviously degenerative or pathological phenomenon of fatty physogastry and the development of exudatoria enable the termitophiles to become true guests, *i. e.*, they can, like the termites themselves, produce exudates which are eagerly devoured by their hosts and in return either receive regurgitated food or manage to prey on the defenseless brood. Wasmann believes that the physogastry and exudatoria are produced through "amical selection" by the termites, much as fat breeds of pigs and cattle are produced by man's selective activities, but such a hypothesis seems to me even less acceptable than the very similar hypothesis which he advanced to account for the symphilic myrmecophiles.

Of more importance in the lives of the termites than their physogastric guests are the numerous intestinal Infusoria which have been studied by more than a score of investigators since they were first described by Lespes in 1856 and Leidy in 1877. These Infusoria occur as a rule only in the soldier and worker. They have been found in many species of termites in all parts of their range and have been variously interpreted as parasites, commensals and symbionts. Imms, who has published the most recent account of their behavior, regards them as true symbionts, which break down the particles of ingested wood and render them more easily assimilable by the termites. Animals as high in the scale as insects must find it difficult or impossible to digest crude cellu-

lose. It is therefore interesting to observe, as Imms remarks, that the symbiosis between the intestinal Protozoa and the termites is paralleléd by the occurrence of numerous genera of Infusoria in the stomachs of ruminants, notably of the ox, sheep, goat, camel and reindeer. "It is believed that, by means of their action upon the vegetable matter consumed by the Ruminants, these Infusoria help to render it capable of being digested by the latter. Furthermore, Infusoria are absent from the stomachs of the young Ruminants prior to being weaned from their parents (*vide* Neveu-Lemaire, 1912, p. 446). According to Certes (1889), glycogen is present in the protoplasm of the Infusoria, and the latter perform a special rôle in the digestive process of the Ruminants. Gruby and Delafond (1843) maintain that the protoplasm of the Infusoria is itself digested, and thereby contributes towards the nutrition of the host Ruminant. Similarly, the Infusoria inhabiting the large intestine of the Equidæ are possibly symbiotic in their relations with their host."

In conclusion I shall have time to dwell on only a few of the many considerations suggested by the singular parallelisms or convergencies between the termites and the ants, such as the development in both of wingless worker and soldier castes, similar nesting and fungus-growing habits, trophallaxis, relations to guests, etc. The duplication of these phenomena in groups so wide asunder that they are placed by systematists at the opposite poles of our classification of insects may be of some interest to the anthropologist, because the study of human cultures reveals the same or very similar institutions and linguistic peculiarities in geographically widely separated peoples. Some anthropologists attribute such similarities to community of origin, while others insist that they are often inventions of independent origin and development. When we reflect that ants and termites have been able, through slow physiological and instinctive processes, independently to evolve such strikingly analogous peculiarities as those I have described, we can scarcely doubt that different human communities, belonging to the same species and endowed with some intelligence, may frequently have hit upon the same inventions.

A less obvious consideration is suggested by the investigations of Holmgren, who finds that as we advance in our study of the termites from the lowest family, the Protermitidæ, to the highest, the Metatermitidæ, we notice a distinct physical, or morphological deterioration in the species and a concomitant improvement of the nervous system. These changes he attributes to advancing social organization. A study of the ants as a group certainly reveals a similar but much feebler tendency of the same kind as we pass

from the more primitive Ponerinæ to the highly specialized Formicinæ and Dolichoderinæ. And it is interesting to note that human society appears to be tending in the same direction. We are becoming accustomed to the thought that our remote posterity will be toothless, hairless and without olfactory organs, toes and possibly other appurtenances, but we console ourselves with the hope that they will have more and better grey matter and a better social behavior than ourselves. We must look forward, however, not only to physical losses in our descendants but to the loss of many of our institutions and customs, for progressive evolution involves not only an acquisition but also a loss of characters. As De Moor, Massart and Vandervelde have pointed out, "all progress must necessarily be attended by degeneration." This explains why the older generation is always scandalized by the young and never remembers that it scandalized its parents.

In termites the amount of degeneration accompanying social evolution is, as stated, much greater than in the ants, and this degeneration seems to have been brought about very largely by an increasing need for protection. With greater elaboration and solidity of nest architecture the termite colonies came to shut themselves off more and more from the outside world, and all the castes, except the winged males and females, lost their eyes and the tough consistency of their integument. They thus came to resemble the mollusks, crustaceans and certain fishes and reptiles which have withdrawn within a heavy protective armor, and have given up participating in the free competitive and cooperative life of their environment. The ants, with the exception of certain subterranean species, have not been inveigled into adopting this passive and timorous mode of life. Hence it is conceivable that some of the more plastic ant-genera may be or may come to be centers of progressive evolution, but there is every reason to believe that the termites have already reached the end of their course. Until recently we might have been tempted to say the same of certain human races like the Chinese and Koreans, who have shut themselves off for long periods from intercourse with other races, but fortunately the human species is still so young that even centuries of such behavior have failed to leave their imprint on the physical organization, and as long as the more resilient mental and social activities alone are affected, there is always hope of a return to the more open cooperative and competitive life which constitutes the basis of progressive evolution.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson
Science Service, Washington

GEOLOGISTS GET AN EXTENSION OF TIME

There was a deadlock between the astronomers and geologists at the beginning of this century. The geologists, having been converted to evolution by Darwin, needed lots of time for the development of the varied forms of life by the gradual process of natural selection, the only process they knew. Then, too, they figured out that it must have taken at least 300,000,000 years to lay the sedimentary rocks and to make the ocean as salt as it is. Man, who is one of the latest settlers on this planet, seems to have been here more than 250,000 years, and the earliest fossils are buried so deep that animal life must have existed some 60,000,000 years at the lowest estimate.

But here the astronomers and physicists interposed a veto on the geologists and paleontologists: "You can't have anything like such a length of time," they said, "for the earth was a molten mass long after the time when you say life began, and was a fiery gas-ball long after you talk of oceans. The earth is the offspring of the sun and the sun itself is only 20,000,000 years old."

This time limit was the estimate of Lord Kelvin, based upon the idea that the sun's heat came from its contraction by gravitation, for no other source of its heat was surmised at that time. He figured out that if all the particles of matter that make up the sun had fallen together from an infinite distance the heat produced by their impact would not be more than enough to keep the sun radiating at its present rate for more than twenty million years.

If, however, somebody should discover another and more abundant source of heat than the shrinkage of the sun, then, of course, the astronomers would be willing to grant the geologists an extension of time for the building up of the world and its inhabitants.

Well, somebody did discover an unknown source of heat abundant enough to satisfy the most extreme demands of the astronomers. This was Madame Curie with her radium, a metal that is continually giving off heat from a secret store within its atom. It appeared then that some of the heavy elements in breaking down into lighter ones, as radium breaks down into lead and helium, give off large amounts of heat for thousands of years. It was later found that atoms of a light element might combine together to form a heavier element and likewise give off heat in immense quantities. For instance, if a pound of hydrogen were to condense to form helium the resulting helium would weigh a little less than a pound, but there would be given off as much heat as would be produced by the burning of 10,000 tons of coal.

Unfortunately no way is known of working this process, so it will not help us out in this winter's coal shortage, but it has helped the astronomers and geologists out of their dilemma. For the astronomers, having now a source of heat sufficient to keep the sun and stars a-going for as long as even they can imagine, can afford to be generous with the geologists in the matter of time. Professor Eddington, of Cambridge, made this concession handsomely when he said recently:

THE CONFERRING OF THE NOBEL PRIZES AT STOCKHOLM

The Nobel Prizes, each of which is of the value of about $40,000, are conferred annually at Stockholm, at which time each recipient is expected to make an address. In the front row to the left are Professor Niels Bohr, of Copenhagen, Professor Francis William Aston, of Cambridge, and Professor Frederick Soddy, of Oxford, who have received the prizes, respectively, for physics in 1921, for chemistry in 1922 and for chemistry in 1921. At the speaker's desk is Professor Henrik Schuck, of Upsala University, head of the Nobel Institute.

"Lord Kelvin's estimate of the extent of geological time need not now be taken any more seriously than Archbishop Ussher's and the geologist may claim anything up to ten thousand million years without provoking a murmur from astronomers."

This liberal allowance ought to satisfy the geologists, especially since they have learned from Mendel that evolution may proceed by jumps instead of by the slow accumulation of minute variations which Darwin had in mind.

HIGHWAYS OF KNOWLEDGE

The first need of a backward country is better communications, roads and railroads, telegraphs and telephones, so the separated settlements of the wilderness can get into touch with each other.

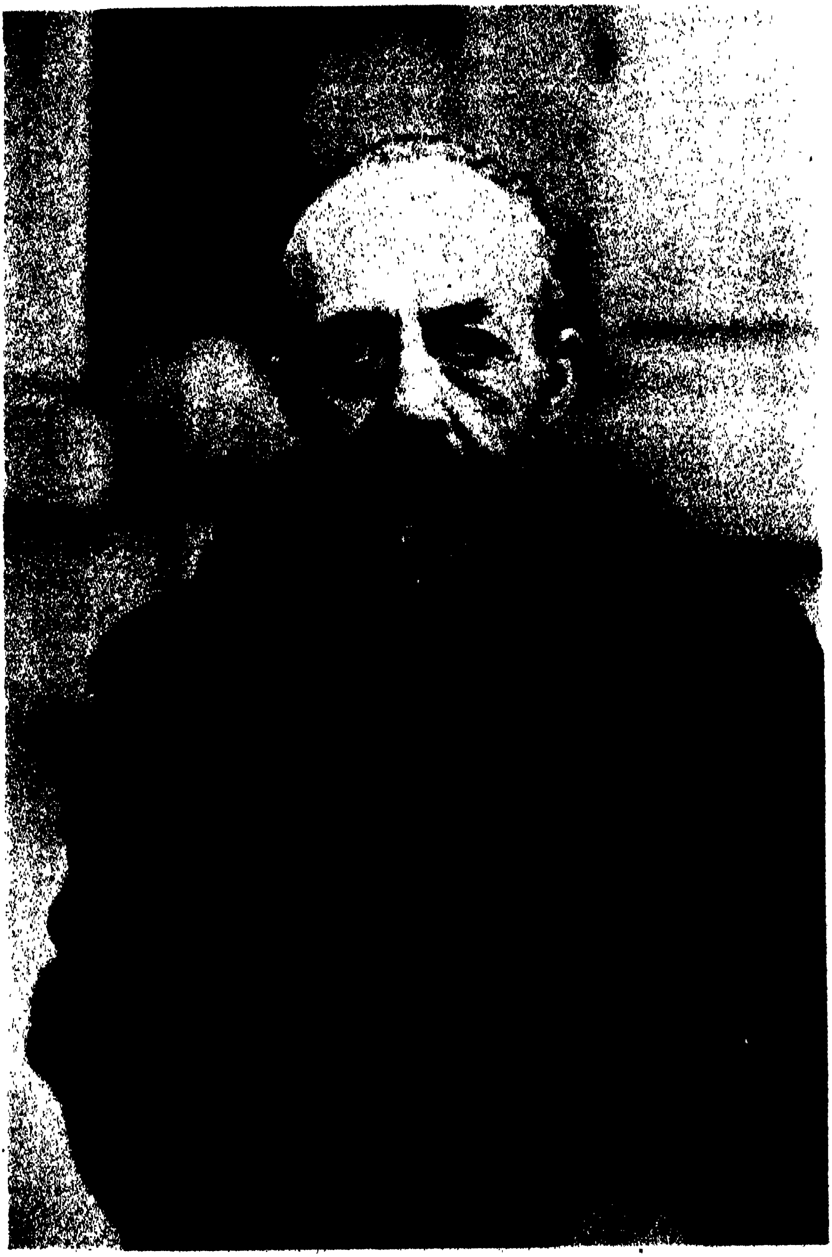
This world is a wilderness, scattered oases of civilization in vast areas of ignorance. Thinkers are few and far apart. Intercommunication of ideas is retarded, often stopped altogether, by the barrier of language as traffic is interfered with by a change of rail gauge at the frontier. Even in the same country minds of different training fail to gear. It does not matter so much if we do not know "how the other half lives," but it is of the highest importance that we know how the other half thinks, especially that smaller fraction of humanity which is thinking for the next century, namely, scientific investigators.

The amount of knowledge accumulated during the last three hundred years since man began the systematic investigation of nature looks large compared with the ignorance that preceded, but looks small when we compare it with what nobody yet knows. What is worse, this precious and painfully acquired knowledge is contained in a few small and perishable packages. I do not mean books, I mean brains. We say "knowledge is power" but the knowledge that lies in libraries has no more power than unmined coal. Can that be called "knowledge" which nobody knows? If all the books in the world were suddenly destroyed how much learning would be left? And how many heads would be holding it?

Professor J. Arthur Thomson, of the University of Aberdeen, puts the point in his usual effective fashion when he says in his book on "The Control of Life": "When we think of the more effective and less wasteful exploration of the earth, or of gathering the harvest of the sea, or of making occupations more wholesome, or beautifying human surroundings, or of exterminating infectious diseases, or raising the health rate, or of improving the physique of the race, or of recognizing the physiological side of education, we are amazed at the non-utilization of valuable—though confessedly incomplete—scientific knowledge. Much has been done, but it must be confessed that man has been slow to follow science in the possession of his kingdom. Part of the reason is that we have not become accustomed, except in some directions, *e. g.*, medical treatment, *to believe in science;* but a great part of the reason is a deficiency of character, that we do not care enough, that we lack resolution."

That is plain speaking and goes to the bottom of the difficulty. It is "deficiency of character, that we do not care enough" to even learn what little has been learned about the management of matter and especially the management of mankind. Science may be discovered by the few, but it has to be applied by the many.

Waste of energy, waste of natural resources, waste of life, waste of time, all forms of waste go back to the waste of ideas. For there is already enough wisdom in the world to make the whole human race more comfortable, healthy and prosperous than any individuals have so far been. But no country is yet thoroughly civilized, even from the stand-



Wide World Photos

PROFESSOR EMMANUEL DE MARGERIE

Professor of geology in the University of Strasbourg, who is now lecturing in the United States.

point of our present knowledge. To bring that about we must bridge the rivers of ignorance and new highways through the jungles of superstition.

PERCENTAGE ALIVENESS

WHEN I dropped into Professor Winthrop J. V. Osterhout's laboratory at Wood's Hole by the sea I found him at first quite too busy to talk to me. Every minute or two his assistant would hand him a porcelain dish containing a few drops of cell sap which he would hastily analyze by counting the number of drops from a pipette that would change its color. It was a familiar chemical test and in fact I would have thought myself in the laboratory of a chemist instead of a botanist if it had not been for some basins of dank seaweed lying around. There was a lot of electrical apparatus, too, galvanometers, resistance boxes and the like, such as no botanist ever bothered with in the days when I was young.

In those days the boundaries between the sciences were well defined and a professor knew what he was professor of. Even if he taught two or more sciences he was careful not to mix them. A botanist did not have any use for a chemist unless he wanted to borrow paraffin or alcohol from him. Now the botanists and zoologists seem to be going over in a body to chemistry and physics. And it is a question how much will be left of the biological sciences when the physical sciences get what they want out of them.

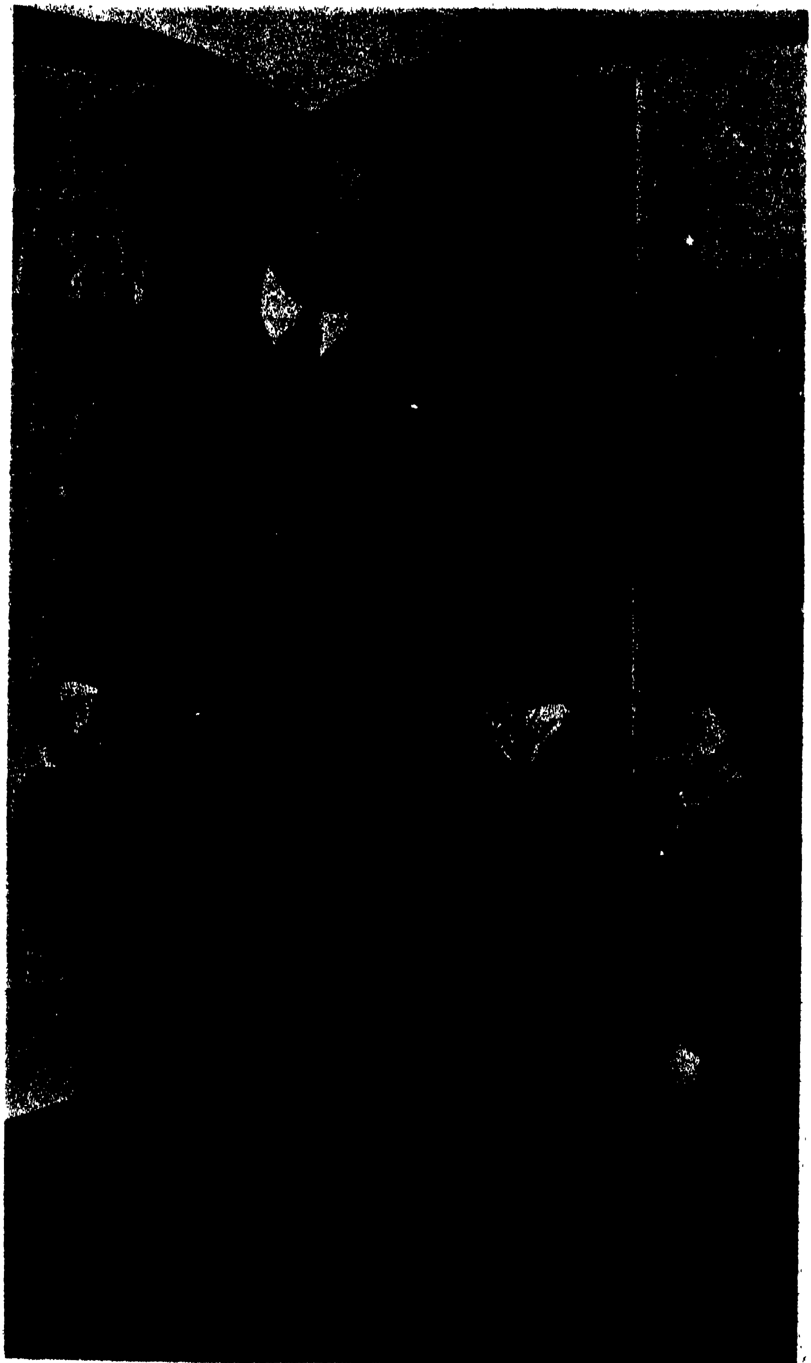
The differences between the old botany and the new became still more apparent to me when Professor Osterhout explained to me what he was doing and what he was aiming at. He was endeavoring to apply quantitative measurement to the processes of life, to find mathematical formulas that would show just how much a plant or animal cell is alive or how near it is to the zero point, which we call death. Mathematics is another thing that the old-fashioned botanist had no use for. It is as easy to count the petals on a flower as to count one's fingers. But Professor Osterhout's new book, "Injury, Recovery and Death," is chock-full of mathematical symbols of the toughest sort.

He finds one of the best ways to measure vitality is to determine how well a cell conducts electricity. For the protoplasm that fills all cells offers considerable resistance to the passage of a current so long as it is alive, but as soon as it is dead its resistance falls off. If it is partly dead its resistance is measurably reduced.

Give Professor Osterhout various samples of seaweed of which some are thriving and others have been injured in varying degrees by putting them into water that is too fresh or too salt, or by exposure to hot sunshine or by poisoning with nicotine. They all look equally green and healthy, but by testing the conductivity he can tell you which have been injured the most and how much.

What is more, he can tell which have been injured beyond recovery and which will be restored to a state of normalcy on being put back into ordinary seawater. If, for instance, a strip of eel grass has been injured to the extent of five per cent. by over-salting, it will recover fully when it gets back into its native element. But if it has been injured 25 per cent. its electrical resistance rises to only 90 per cent. of the normal. If the injury amounts to 90 per cent. there is no recovery.

He finds whatever alters the electrical conductivity of plant or animal tissue, whether it be a crushing blow, too much heat, lack of air, lack of water, presence of poisons or anything else, will shorten or impair the life of the organism. He comes to the conclusion that life is a series of balanced chemical processes and that when this balance is disturbed by a change in the environment one process goes faster than another and



Wide World Photos

FATHER AND SON

M. Ratoucheff, the Russian impresario, with his son André, who is twenty years of age. The son, who is twenty-six inches in height, is the leader of the Russian Midgets now playing in London. M. Ratoucheff is six feet four inches.

Wide World Photos

TWINS IN ONE FAMILY

Four sets of twins in a family at Martin's Ferry, Ohio There are in the family two other children who are not twins.

then the creature grows or decays, thrives or declines. Dying is therefore a normal part of living. The only danger is in its getting to going too fast.

Professor Osterhout does not say anything about the application of his discoveries and theories to human life. So far as I know he has not carried his experiments farther up the scale of life than frog's skin. So it will be some time before we can know whether there is any sense in our crude quantitative expressions of vitality, "I feel half dead" or "more dead than alive," by which we mean usually that we are "dead tired."

THE ANCESTRAL SCANDALS OF SCIENCE

TRACING back the history of a science is like searching out a genealogy; one is sure to unearth something scandalous if he goes back far enough. John G. Saxe warned the would-be ancestor worshipper of this danger in the familiar lines:

> Depend upon it, my snobbish friend,
> Your family thread you can't ascend,
> Without good reason to apprehend
> You may find it waxed at the farther end
> By some plebeian vocation!
> Or, worse than that, your boasted line
> May end in a loop of a stronger twine,
> That plagued some worthy relation.

The chemist handles with reverent awe the latest unearthed and earliest written text of his science, a scrap of Egyptian papyrus, but when he gets it translated he finds it is a counterfeiter's recipe, a method of making base metals look like gold. Or else it is a recipe for cosmetics which is also a form of counterfeiting.

The astronomer finds in a Babylonian brick the first record of the stars but discovers to his disgust that the cuneiform inscription is an astrological treatise, a fortune teller handbook.

Hero of Alexandria described the turbine steam-engine, the coin-in-a-slot machine and other valuable inventions. But what were they invented for? So the priests of the

temple of Isis could perform fake miracles.

Pythagoras discovered the law of the hypotenuse—and was so happy over it that he killed a hundred oxen. It is hard for us to see why. But mathematics was to him a form of magic, otherwise he would not have been interested in it.

Paracelsus did much to advance medicine. We can not yet dispense with the three drugs he introduced, mercury, opium and antimony. But Paracelsus's real name was Bombast —and he lived up to it.

It is humiliating to confess, but the progress of science in its early days owed much to the false pretensions of its practitioners. Kings would not have kept a corps of men studying the stars unless they had proffered practical returns in the way of auguries. Chemists were subsidized for centuries because they promised the philosopher's stone and the elixir of life—promises not yet fulfilled.

Columbus would not have ventured to cross the Atlantic if he had not been wrong in his figuring about the size of the earth and his royal backers would not have put up the money for the voyage if he had not told them wrongly that he could reach India that way.

Ponce de Leon was led to Florida by his search for a mythical Fountain of Youth. Coronado explored the Kansas plains to find the fabulous Seven Cities of Cibola. The vain search for the impracticable Northwest Passage to Asia was the stimulus to exploration for a century.

Fortunately for the world, fictitious aims may lead to real results. The scientist has learned how to achieve greater miracles than he ever pretended to perform. Truth has grown up under the shadow of error as infant oaks get their start under the shelter of worthless weeds. In chasing a will-o-the-wisp one may catch sight of a fixed star. Falsity has often served as a guide to Truth.

If the alchemist and the astronomer had been frank with their royal patrons and said: "No, we can not promise you gold from lead, or everlasting life, or the power of reading fate in the stars, but if you will grubstake us and our successors for two thousand years we may be able then to tell you the size of the universe and the structure of the atom," they would have been laughed at instead of getting a share of the king's bounty. Even were they to have added the further promise, "If given a chance to devote our lives to science we will, beside said increase of human knowledge, throw in dynamos, bridges, coal-tar dyes and the like," still the ancient monarchs, being near-sighted, like all men, would have refused to come down with the cash for the benefit of a remote posterity.

But science now-a-days can show such practical profits that it is beginning to get funds for research without pretending to do more than it knows it can. Science can safely promise rich rewards for money spent in its advancement, but it can not say when or in what coin the world will get dividends on such investment in future.

SCIENTIFIC ITEMS

We record with regret the death of Edward E. Barnard, professor of astronomy in the University of Chicago and astronomer of the Yerkes Observatory; of Bernhard Eduard Fernow, professor emeritus of forestry in the University of Toronto; of Wilhelm Konrad Roentgen, professor of physics in the University of Munich, who obtained in 1895 a world-wide reputation by the discovery of the X-rays; of H. G. van de Sande Bakhuyzen, formerly director of the Leyden Observatory; and of Johannes Orth, successor of Virchow at the Berlin Pathological Institute.

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THE CONSERVATION AND UTILIZATION OF NATURAL RESOURCES[1]

THE NATIONAL PROBLEM OF LAND RECLAMATION

By F. H. NEWELL

U. S. RECLAMATION SERVICE, WASHINGTON, D. C.

THE nation is committed to a policy of reclamation and use of the portions of its public and other lands which, having a tillable soil, are not available for farms until there has been a regulation of the water supply essential to the proper growth of plant life. The object of this reclamation, as stated by its advocates, is the making of small self-supporting farm homes. This object is summed up in a message from the Secretary of the Interior, Albert B. Fall, on the twentieth anniversary of the passage of the act in the words that "the success of the law must be measured by the extent to which the reclaimed lands are utilized in the making of self-supporting American homes."

The point emphasized in this policy of conservation and use of otherwise waste land is that the fundamental purpose is not merely the increase of material prosperity—the making of money through greater crop production—or even of adding to the food supply of the nation, important as this may be at the time. The real objective rises to a far higher level, that of ministering to what may be called, for lack of better words, the social and spiritual needs of the people through making possible the creation of the small self-supporting farm home, in which may be exemplified the American ideals of "life, liberty and the pursuit of happiness." It has long been urged by popular speakers and others that it is the citizenship of the farm home which forms the backbone of the

[1] Papers presented before the Section of Social and Economic Sciences of the American Association for the Advancement of Science at the Boston meeting, December 27 to 30, 1922.

nation. It is upon the rural districts that we depend for stability of government and business institutions. We look to the country vote to offset the threat of Bolshevism in the cities. Our Constitution is based upon the assumption that a considerable proportion of the voters of the country are tax-paying citizens who own their homes or at least have a direct interest in the support of our governmental institutions. When the time arrives, as it threatens to do, that the great majority of the voters have no proprietary interest in anything beyond an automobile, when they believe that it is the landlord who must pay the taxes, then their interest in the economy and efficiency of public affairs wanes to an extent dangerous to any government.

Under such assumptions a reclamation act applicable to the sparsely settled, arid western states was urged by President Roosevelt in his first message to Congress in 1901; and on June 17, Bunker Hill Day, in 1902, he attached his signature to this act, marking a distinct departure in American policy.

Up to this time the public lands had been sold at nominal prices or given away on condition of settlement and cultivation. Now, however, with the rapid disappearance of these public lands, a new policy was adopted—that of practically creating new available lands by reclaiming such lands and removing the natural obstacles; in other words, by extending internally the territories of the United States.

Funds were provided for this reclamation by setting aside the proceeds of the disposal of public lands; in twenty years these proceeds have amounted to $105,000,000. They have been supplemented, and a loan of $20,000,000 has been added to them, so that over $130,000,000 has been made available. Most of this has been invested in the construction of works for the storage of flood waters, the building of canals to carry this water to the lands and the digging of ditches to drain away excess water. About thirty thousand farm units or opportunities for the creation of thirty thousand farm homes on the land have been created. These have been rapidly taken up, the land, so far as it is in public ownership, being given away on condition of settlement, cultivation and repayment of the construction charge. The money invested by the government in the building of the works is to be returned without profit or interest, and in instalments covering 20 years, without interest.

All of the works have been completed to a point where self-supporting small farm homes have been established, and there has been produced from these lands a gross value of crops aggregating $475,000,000. To this should be added the revenue from livestock. It should also be borne in mind that many structures have been

built in part and are being completed as rapidly as funds are available; and that most of the farmers have not yet brought under full cultivation all of the lands in their possession. Development of a new pioneer country takes time and demands infinite patience as well as hard labor and self-denial.

Enough has been done in the arid western states to show what can be accomplished as need arises in other parts of the country. While the government does not own any considerable area of land in the country east of Kansas, yet there are waste, or unused lands, which may be made available under similar methods.

For example, throughout the length and breadth of the country, from Maine to Louisiana and from Minnesota to Florida, are great tracts of cut-over lands or abandoned areas, where, because of interstate or other complications, it has not been possible to provide adequate drainage, or to get the land, with fairly fertile soil, into condition for settlement. The owners of these lands—especially of the cut-over forest lands—are feeling the burden of the taxation levied for the building of good roads and bridges, the maintenance of community schools, the erection of court houses and other public buildings. Some of this land is being sold for taxes. Most of it should be kept in permanent forest, but until the people awaken to the necessity of developing the policy for keeping the lands in forests, the lands must necessarily deteriorate.

When mention is made of the possibility of the government reclaiming or making available for settlement any of these cut-over lands, there arises at once a hysterical outburst that this is merely a scheme to help the wealthy lumbermen to unload worthless land upon the government. It is loudly declared that the government is always victimized in any deal of this kind, and that any man who advocates the development of these unused lands and the creation of small farm homes on the portions which have fertile soil must, necessarily, be in the pay of the lumbermen!

We can avoid this talk by stating at the outset that it is practicable for the government to adopt a policy of land reclamation without the necessity of buying great areas of land or of enriching the owners of cut-over lands. It is possible for the government to act as a trustee, and to pass the title of the reclaimed lands at prices agreed upon in advance directly from the present owners to the settlers who may establish homes thereon, and to see to it that they are not robbed in the process.

Dismissing such fear, it then becomes practicable to consider a broad program of land reclamation and use in the creation of farm homes in any or all parts of the United States where the climate, soil, social and market conditions are favorable.

First, however, must be considered the need of such farms:

We start out with the assumption that the stability of government and of business is dependent on the farm home; but, again, it may properly be asked as to whether there are not already enough of these and whether there is need for more. The present tendency, as shown by census reports, is that of a relative decrease; more and more families are going to the cities, big and little, because there they find not only larger wages, but more enjoyable surroundings. Some of our economists claim that the development of farming as an industry is bound to proceed along lines of greater intensity, of increasing product per individual and thus of requiring fewer individuals on the farm.

Carried to the logical conclusion, some publicists would go so far even as to assert that the best economic developments of the country will come about when farms are operated under the same methods as the Ford factories, or other great manufacturing concerns, where one or two men supply the brains, and where the work of each of the thousands of employees is minutely apportioned, consisting merely of turning a screw or pushing a wire through a hole. In line with this, these people urge that we should provide for the importation of Chinese or other Asiatic labor, with the provision that these coolies may be employed for a certain number of years, and then returned to their native countries; in other words, creating a condition of serfdom analogous in some of its methods to the slavery of olden times, under which great crops were produced. On the other hand, it is urged that no body of people should be admitted to the United States who are not qualified to make permanent homes and become assimilated with the people already here.

The whole spirit of our institutions is that the success of our government rests upon the citizens themselves, and that can not be raised higher than its source. For this reason it may well be questioned as to whether it is wise in the long run to encourage any type of manufacture or even of agriculture which requires inferior labor or creates the slum conditions prevalent in manufacturing centers.

In answer to the question as to whether we have enough small self-supporting farm homes, it may be shown that if the country continues to grow as in the past, and if there is a steady decrease in the proportion of such farm homes, even then there will be needed opportunities for new homes at a rate of say 300 per day. In other words, unless the number of farm homes is to decrease relatively, there must be some provision made for the future.

Where can these 300 new farm homes be found? Where can the country-minded young man and his wife look for a piece of

land? The answer from some of our economist friends is that he should not hope for a farm of his own at once; he should serve as a farm laborer, then as a renter, and, in the course of years, if he has worked skillfully and well, if he has been fortunate and at the same time thrifty, he may in middle age acquire some of the farm lands, the prices for which have been steadily advancing. In other words, he should climb the agricultural ladder, and, in the orderly course of events, arrive at the top, unless he falls off on the way up.

Other publicists ask whether it is desirable and necessary for these families to climb the agricultural ladder with all of its discouragements, due to the fact that for the greater part of his life the young man must be enriching the farm of some other man (assuming that he is not robbing it of its fertility). Can not society, or the government, in a country where half of the land is unused, make conditions such that the competent man may not be obliged to climb the ladder, typical of a temporary or unfinished structure? By coming in on the ground floor, he may begin at once to work on a farm of his own, where he may be able to gratify the passion for possession, and will be stimulated to think and work for himself in a way which he never would for any other man.

There is nothing in the physical conditions of the country nor its laws and precedents which forbid such ambitions. There already exist, in the results from the present Reclamation Act, ample precedent and inspiration for extending the benefits more widely. It is possible to say to every qualified seeker of a small farm home: "There is good land available which you can have upon such terms that you can make a home on the land, and need not risk your fortune and family in the laborious, unsatisfactory task of climbing the agricultural ladder from serfdom to ownership."

It is admitted, of course, that not every man who thinks he would like to have a small farm home is capable of making a success, no more than should it be assumed that every man who enlists in the army or seeks employment is capable of performing the duties or can pass the necessary tests for such employment. There must and should be for the good of the man himself tests which will eliminate those who are really unqualified. It frequently happens that the men who first apply are those who are habitually unsettled—the rainbow chasers, hunting the "pot of gold" and with no conception of the difficulties to be overcome.

Assuming, however, that good common sense is employed, with the guidance available from years of experience in reclamation

and settlement on the lands, then it is not merely practicable, but is a matter of sound public policy to improve the present machinery, and to extend to all parts of the United States the beneficent effects of a national reclamation act which will provide for the bringing into a condition suitable for cultivation all fertile lands now unused and making these available for the creation of small self-sustaining farm homes.

It might be urged that on similar grounds the government should provide equal opportunities for owners of small factories, for blacksmiths and for shoemakers. But there is a line which must be carefully drawn and rigidly observed, which is based on the fundamental distinction for the small farm home is not primarily a money-making institution, but is essentially a home for citizens.

The fear has been expressed that the country would thus be flooded, and millions or billions of dollars would thus be required for reclamation; in other words, that if the door of opportunity was once opened for the creation of such homes there would be such a rush and jam at the doorway as to practically upset all present social conditions. There need be little fear, however, in this direction. It is true the advocates of great schemes like those in the northwest, in the Columbia Basin, and in the southwest, on the Colorado, talk easily of hundreds of millions of dollars required for such reclamation; and that if amounts needed for all of the other work in all parts of the country is added up the amount exceeds the ability of the mind to grasp. As a matter of fact, the amount of money which could or would be granted by any Congress under any conceivable condition will always be far less than the actual needs, and the continual poverty in this respect will act as a brake or safeguard against entering into the wild undertaking so glowingly pictured by the extremist friends of the national policy.

In the long run the adoption of a policy of land reclamation and settlement on the part of the federal government should and will serve as more or less of a pace-maker for the activities of the states and semi-public corporations or municipalities created under the state laws for the drainage and development of various areas. It may be safely assumed that the federal government, as in the case of present irrigation enterprises, will continue to confine its efforts to those undertakings which are naturally beyond the reach of corporate or state effort.

In summing up, it may be said that of reclaimable public lands of the country, and of adjacent unused private lands with fertile soil, there are say 10,000,000 acres which may and should be pro-

vided with an adequate water supply. In other parts of the country there are bodies of land in private ownership, now unused, and which may be reclaimed by drainage and other means, aggregating at a conservative estimate 20,000,000 acres. In other words, there are perhaps 30,000,000 acres of reclaimable land which has been examined in whole or in part, and found to be suitable for the creation of small self-supporting farm homes, to the number of over a half million.

There are no obstacles in this reclamation which have not already been overcome; there is a need for the increase not merely in production on the lands already in use, but for the homes for which larger needs grow imperative. It would seem to be the part of wisdom to extend the Reclamation Act to permit the taking up of other land in a systematic, orderly manner, for the benefit of the states and of the nation.

PROBLEMS OF FLOOD CONTROL

By Brigadier General HARRY TAYLOR
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FLOOD control is a broad subject with many phases. Anything approaching a complete discussion of any one of the more important phases would take more time than I feel I can devote to it in the time assigned me, as it is only one of many important matters to be discussed at this meeting. I shall, therefore, try to give you a general view of the most important aspects of flood control. I shall refer at some length to the problem of flood control on the Mississippi River as that is the most important in the country, and shall quote Colonel C. McD. Townsend, formerly president of the Mississippi River Commission, who has devoted a large part of his life to the study of this subject.

It may be well to ask at the outset what are the causes of floods. The answer is, briefly, abnormal rainfall. This rainfall may be either in the shape of what is popularly known as a "cloudburst," such as occurred at Pueblo, Colorado, in June, 1921; in the shape of heavy, long-continued rains such as produced the floods in the lower Mississippi River in February and March last, or heavy rains falling on snow or frozen ground, such as produced the floods which devastated Dayton and other cities of Ohio a few years ago. Warm winds blowing on a heavy blanket of snow may also produce a serious flood. Floods of this character are most common in the Pacific Northwest where a warm southwest wind, known as a "Chinook" wind, occurs during the winter months and causes

the snow on the mountains to melt with great rapidity. The floods caused by the so-called cloudburst are usually local in character and commonly occur on small streams. Floods caused by the long, heavy rainfall usually cover a large territory and it often happens that such rainfall will produce a flood in the main stream when none of the tributaries are subject to excessive flood. This occurred during the past winter and spring in the lower Mississippi, when that stream carried one of the largest floods in history, while none of its tributaries carried an unusual flood, but all of the lower tributaries carried moderate quotas. The floods caused by rains falling on snow or frozen ground generally affect an area intermediate between the other two types.

Outside of the Mississippi Valley the people of the United States ordinarily give little thought to the control of floods. It is only when some serious flood occurs that attention is focused on the prevention of a repetition of the disasters caused by such flood, and then the matter is of extreme interest for a short time with all sorts of remedies proposed. Dayton, Ohio, is one exception. It is characteristic of the American people that when we suffer from any cause such as a flood, a contagious disease, or war, we are wildly enthusiastic for steps to prevent a repetition of the disaster, but as soon as the time of stress has passed we forget that trouble has occurred and delay taking the steps necessary to prevent a repetition. This is well illustrated by the present attitude of the American people toward the army. Five years ago there was nothing too good for the army. To-day, many seem to desire its absolute abolition, forgetting the fact that it is an insurance against trouble in the future. I wish that I could believe that we will never be involved in another war. I wish also that I could believe that we will never have a disastrous flood, but I am certain that floods will come until we know how to control the distribution of rainfall, and I am equally certain that the services of the army will be required in the future.

The control of floods appears to be considered by the majority of our people as a simple problem. It is true that different people have different solutions. The most common solutions are reforestation, reservoirs at the sources of the streams, levees, outlets or spillways, and straightening and enlarging river beds. We frequently have other solutions suggested, as, for example, one proposed to install boilers on the banks of the Mississippi River to evaporate the flood waters, thus causing clouds to form and produce rain over the middle west where needed.

In the solutions proposed the control of floods is quite commonly linked with other beneficial effects, most commonly with water-

power development. It is generally assumed that the same work which will control floods will produce power, improve navigation and provide drainage. One very troublesome problem that comes before the engineer department is the problem of the Fox River and Lake Winnebago, Wisconsin. At the outlet of Lake Winnebago are constructed two dams provided with gates for controlling the water outflow from this lake. The lake is surrounded by flat land over which the flowage rights were purchased and paid for by the United States some fifty years ago. Since that time these lands have been sold and the buyers in many cases have apparently made their purchases unaware of the rights of the government. Invariably during floods on this stream the people above the dams insist on the gates being opened so as to permit the water to flow out rapidly; the people below the dams insist on the gates being closed so as to prevent the water from coming down on them; power interests on the lower river desire to have the water retained and released during periods of low water for the purpose of developing additional power; for the benefit of navigation the flow should be as uniform as possible.

With reference to reforestation, I desire to say that I am a thorough believer in a sensible and sane system of reforestation. I believe that the proper exploitation of our few remaining forests and intelligent reforestation is one of the great needs of the country. Reforestation has sufficient merit in itself to stand on its own feet and should not be mixed up with flood control. The price of lumber to-day is a sufficient argument for planting trees without attempting to associate forestry with the climate or with flood conditions on our rivers.

There appears to exist in the public mind an impression that the prime cause of floods in this country has been the destruction of the forests, and that the surest way to prevent them is by reforestation. The influence of forests on stream flow has been extensively discussed both by European and American engineers since Gustav Wex, imperial and ministerial counselor and engineer of the improvement of the Danube River at Vienna in 1873, submitted a series of papers on the decrease of water in springs, creeks and rivers which were translated into English by the late General Weitzel, of the corps of engineers.

There is a great diversity of opinion on the subject, some maintaining that the cutting off of forests will ultimately convert Europe into a Numidian desert, while others claim that a moderate cutting of the forests even increases the rainfall. Whatever may be the theoretical principles involved, their practical application is fraught with great difficulty.

When a country acquires a population of 100,000,000 people, the forest primeval which existed when it was first settled has to disappear. It is all very well to bemoan the fact that if the black walnut which once covered the state of Ohio had not been destroyed and was sold as lumber at the present market rates it would equal the assessed valuation of the property of the state, but there have now been created the cities of Cleveland and Cincinnati, whose people can not live on black walnuts alone, but require grain and meat. The black walnut of Ohio has gone, never to return, and the same is true of the forests in other sections of the country. The fertile lands will not be taken away from the farmer. They are too valuable for raising potatoes and hogs. Only the poorer soils can be used for forest culture, and only a limited reforestation, then, is possible.

The effect of forests on rainfall in Europe has been carefully investigated, and the records at many European localities where the rain has been recorded for long periods fail to show any tendency to a pronounced change of fall in recent years.

The meteorological records of the United States have not been maintained a sufficient length of time to be of much value in solving the problem. The best existing data in this country of which I am aware are those for the Merrimack river, on which a daily record of the stage of the river has been observed since 1849, on a gauge established below the dam at Lawrence, Massachusetts. An exhaustive study of this stream was made about twelve years ago by Colonel Edward Burr, Corps of Engineers, and a report submitted by him which is published as a government document. Colonel Burr's conclusions as summarized for the basin of the Merrimack River were as follows:

Deforestation of the basin continued progressively from the early settlements until about 1860-1870, and since that period forested areas have increased through natural causes by twenty-five per cent. or more of the entire basin, notwithstanding the continuance of lumbering operations.

There has been no decrease in precipitation in the basin as a result of deforestation or any increase with the reforestation of twenty-five per cent. or more of its area. The precipitation for fifty to ninety years at points within the basin or within a few miles of its borders shows tendencies or cycles that bear no relation to the changes in forest areas.

The average run-off through the river varies with the precipitation over its basin, and the percentage of run-off to precipitation is not appreciably affected by forest changes as great as twenty-five per cent. or more of the basin.

The frequency of floods has not been decreased by reforestation or increased by deforestation.

Exceptionally high floods have occurred at intervals without respect to forest conditions. Flood heights have not been decreased by forestation or increased by deforestation, and the principal characteristics of floods are

unaffected by forest changes. The duration of flood stages and the amount of run-off during such stages have not been affected adversely by deforestation or beneficially by reforestation.

Deforestation has not lessened the height of the river at low water or increased the duration of low-water periods, and the reforestation of twenty-five per cent. or more of the basin has not had any beneficial effect on low stages of the river.

Variations in stream flow are determined essentially by variations in climatic conditions which move in irregular cycles independent of forest changes.

Correct deductions as to climatic variations and as to varying conditions of stream flow may be expected only from the analysis of satisfactory records covering periods of sixty years or more, and conclusions drawn from records extending through forty years or less may and probably will be misleading or incorrect.

The greatest flood of the Mississippi at St. Louis occurred in 1844, the next largest in 1875. On the Great Lakes the high water of 1838 is the greatest on record. In the Ohio the flood of 1884 exceeded that of 1913 at Cincinnati; and that of 1832, while five feet lower at Cincinnati, was five feet higher at Pittsburgh than the 1913 flood. The gauge records at the bridges over the Upper Mississippi, which cover a period of thirty years, would indicate that the flow from Minnesota and Wisconsin, where the forests have been most extensively destroyed during the period, has been slightly improved, though the river shows signs of deterioration where it receives the flow from the prairie lands of Iowa and Illinois. They appear to confirm the conclusion of the European forestry authorities that the influence of forests on drainage is concealed by other causes more powerful in their effects.

It is, however, argued by some that with reforestation if the floods occasionally were high they would not be as frequent. Again let us search the records of the past. It is hopeless by reforestation to expect to reproduce the forest growth that existed at the close of the Civil War. Yet from 1857 to 1867 the Mississippi Valley was visited by a most remarkable series of great floods. These floods occurred as frequently as any that have been recorded since that time.

It requires from twenty to fifty years to produce a good forest growth, and over a century for the leaves of that forest to decay in sufficient quantities to produce the humus which will be satisfactory as an absorbent of rainfall. We are more vitally interested in the height that a river will attain in the next few months than in what will occur in the year 2022 or 2072. It is pertinent to this discussion to determine what would be the extent of the forest reservation which would be required to reduce the flood heights on the Mississippi River a given amount.

To solve this problem it is necessary to make certain assumptions, and for purposes of argument we will take it for granted that reforestation will reduce the flood discharge of a stream one half. The Mississippi flood of 1912 attained the greatest height of any then recorded at all gauge stations except at Vicksburg. That of January and February, 1913, while five feet lower at Cairo, was the next highest flood at Memphis and for a considerable distance along the river. We will endeavor by reforestation to reduce the flood of 1912 to the heights attained in the winter of 1913. For this purpose it will be necessary to reduce the maximum discharge of the river 500,000 second-feet. It will also be necessary to distribute this reduction among the tributaries, reducing the maximum discharge of the Missouri River from 900,000 to 700,000 second-feet, that of the upper Mississippi from 450,000 to 350,000, and that of the Ohio River from 1,400,000 to 1,200,000.

The flood discharge of the Missouri River at its headwaters is about one cubic foot per second per square mile of drainage area, and, if the reduction in discharge of one half is to be secured by reforestation two square miles of forests would be necessary for every second-foot of reduction of flood discharge, or 400,000 square miles of forests to reduce the discharge of the Missouri River 200,000 second-feet. At the headwaters of the upper Mississippi the ratio of flood discharge to drainage area is about two second-feet per square mile. A reduction of this discharge by one half would require a forest reservation of 100,000 square miles to reduce the floods of the upper Mississippi 100,000 second-feet. On the Ohio River the ratio is 6 to 1, and it would therefore require forests at the headwaters of the Ohio having an area of 33,000 square miles to reduce its flow 200,000 second-feet. In other words, to reduce the height of a flood at Memphis by reforestation at the headwaters of the river from that of 1912 to the next highest on record would require a forest reservation of about 533,000 square miles, an area exceeding that of the portions of Montana and Wyoming drained by the Missouri River and the states of North and South Dakota, the portion of Minnesota drained by the upper Mississippi River, and the states of Iowa, Wisconsin, Illinois and Indiana. But even such a forest reservation would afford only partial protection. Under the above assumptions, to prevent any overflow by reforestation would necessitate a practical abandonment of the valley for agricultural purposes and the development of an extensive irrigation system to produce tree growth in arid regions of the west.

It is therefore apparent that even under the above extreme assumptions reforestation as a means of reducing flood heights on the Mississippi River requires the conversion of too much farming

land into a wilderness to be practicable. The waste land that can profitably be converted into forest reservations is too limited in area to produce an appreciable effect on the floods.

Next to reforestation, reservoirs as a means of controlling floods appear to have the most advocates. The reservoir theory is particularly attractive, as we have before us in the Great Lakes a practical illustration of flood restraint by means of natural reservoirs. Reservoir control of the Mississippi River was discussed by Humphreys and Abbott in 1858, and on the upper Mississippi the corps of engineers has constructed the largest system of reservoirs for regulating rivers that has been built in any country. These reservoirs have been most successful, not only for increasing the low-water discharge of the Mississippi River above St. Paul, the purpose for which they were constructed, but also for reducing floods in that portion of the river.

There is, therefore, nothing novel in the proposition to control rivers by reservoirs. We have not only studied its advantages, but we know its limitations. Conditions are extremely favorable for reservoir construction at the headwaters of the Mississippi, but while they materially increase the low-water discharge at St. Paul and markedly reduce flood heights, yet one hundred miles farther down the river it is impossible to detect their influence during either high or low water.

A reservoir must be close to the locality to be benefited or its value rapidly diminishes, and this is a serious trouble with any project for regulating the lower Mississippi by reservoirs.

To have retained the Mississippi flood of 1912 within its banks would have required a reservoir in the vicinity of Cairo, Illinois, having an area of 7,000 square miles, slightly less than that of the state of Massachusetts, and a depth of about 15 feet, assuming that it would be empty when the river attained a bank-full stage.

Cairo is the logical location for a reservoir to regulate the discharge of the lower Mississippi. It will not only control the floods from the Ohio, but also the discharge from the Missouri and upper Mississippi. But if the reservoirs be transferred from the mouth of the tributaries to the headwaters their capacity must be largely increased. No two floods have the same origin, unless they are referred back to the Gulf of Mexico. If the prevailing winds in the early spring are from the southwest, the southern tributaries of the Ohio furnish the crest of the year's flood; if more nearly from the south, reservoirs will be required on the streams of Ohio, Indiana and Illinois; a slight varying of the wind will produce a flood in the upper Mississippi, while if it blows from the southeast the principal sources of trouble will be the Red, Arkansas and Missouri rivers. To control the flow of every stream in the Mis-

sissippi Valley by reservoirs is a pretty large job even for the United States Government, but that is what the control of the Mississippi during floods by reservoirs signifies.

The 1913 flood affords data for determining the effect of such a system of reservoirs. When, on April 2, 1913, the gauge at Cairo attained a height of 54 feet, there was flowing down the Mississippi River at least 2,000,000 cubic feet of water per second. It requires about eleven days for a flood wave to be transmitted the 966 miles between Pittsburgh, Pennsylvania, and Cairo. On March 22 the Pittsburgh gauge read 5.3 feet, which is produced by a flow in the Ohio River at that locality of about 15,000 second-feet. In ten days a flood travels the 858 miles between St. Paul, Minnesota, and Cairo. On March 2 the reading of the St. Paul gauge was 0.5 foot, corresponding to a discharge of the Mississippi of about 2,500 second-feet. In eight days the effect of a flood at St. Joseph, Missouri, is felt at Cairo. On March 25 the gauge at St. Joseph read minus 0.1 foot, representing a discharge of the Missouri River of about 17,000 second-feet. If a system of reservoirs had been constructed which would have prevented all flow from the Allegheny, the Monongahela, the Mississippi above St. Paul, and the Missouri above St. Joseph, it would have reduced the 2,000,000 second-feet discharge by the Mississippi River at Cairo on April 2 less than 35,000 second-feet.

The water which passed Cairo on the 2d of April came principally from the White and Wabash and the lower tributaries of the Ohio and, after the water of these rivers started to subside, the flood from Cincinnati, though increasing from 57 to 69 feet on the Cincinnati gauge, could increase flood heights at Cairo less than one foot. The flood of 30 feet at Pittsburgh on March 28 produced its effect on the Cairo gauge on April 8. It prolonged the flood without increasing its height.

The proposed system of reservoirs would have cost hundreds of millions of dollars and its effect on the flood height of the lower Mississippi could not possibly have exceeded six inches.

Great floods do not rise from average conditions, but from exceptional conditions such as are caused by a series of heavy rains rapidly succeeding one another. Each rainstorm starts down a stream a flood, the volume of which can be absorbed by a reservoir with comparatively little trouble, but if a second storm sweeps over the valley the reservoir, to be effective, must be emptied or its capacity doubled. To hold all the excess rainfall till low water would require reservoirs of enormous capacity. Economic considerations usually require that the reservoirs should be emptied as soon as the flood crest passes, in order to utilize the same space for a second rainfall; so that while reducing the crest of a flood

at a given locality they necessarily prolong the period during which the river remains at a high stage.

Reservoirs are necessary for municipal water supplies, for purposes of irrigation, for the development of power, and for feeders to canals. They can be successfully employed on small streams to diminish floods or increase the low-water flow. The trouble arises when an attempt is made to utilize them for too many purposes at the same time. There must be a paramount issue to which the others will be subsidiary.

If the main purpose is to supply a city with water, as a rule only the excess can be used for power development. In the case of the new water supply for San Francisco now under construction, a large amount of power will be developed, but in this case the main storage reservoir is over 4,000 feet above the city and the topography is such that at one point the supply line drops about 2,000 feet in a nearly vertical line, giving an excellent opportunity for a power development at a minimum expense and without interfering with the main object of the construction. If the dams are constructed to produce power, the reduction of floods and the improvement of river navigation must be subordinate thereto. Water required for irrigation can be used to develop power when the dam of the storage reservoir is given a greater height than is necessary for its flow over the land to be reclaimed.

During the next decade there will be an enormous development of reservoirs, both for irrigation and for power purposes, which I hope will be utilized to correct man's folly and prevent many disasters similar to those which have occurred in the past.

Levees, properly located and constructed, are an effective means of protection against floods. Levees have been used for many years on the European rivers and have been used to a great extent for the protection of the lands bordering the Mississippi River. At the present time there are 1,779 miles of effective levees in place between Rock Island, Illinois, and the mouth of the Mississippi. These levees contain about 400,421,000 cubic yards of material. The levee system protects about 27,628 square miles of land. At the present time the question of providing additional outlets or spillways on the lower Mississippi is being given great consideration. That the spillway will cause a temporary lowering of the flood water is beyond question, but it is not quite so certain that the ultimate effect of a spillway will be beneficial for the Mississippi, for there is a possibility that the abstraction of the water will cause shoaling of the channel below the spillway which may produce serious results in time. Levees combined with channel enlargement and spillways are being used in the flood control of the Sacramento River. The spillways, however, are of secondary

importance, the main dependence being placed upon levees and the straightening and enlarging of the channel of the river near its mouth so as to afford a freer escape of the flood waters.

In locating levees care must be exercised not to place them so near the banks of the river as to unduly crowd the stream and reduce the cross-sectional area sufficiently to prevent the escape of flood waters without causing their rise to a height such that they will overtop the levees. The great tendency is for the owners of the land on each side of the stream to crowd the levee as close to the bank of the stream as possible, leaving too little space for the escape of flood waters, with disastrous results to both sides.

Another serious tendency is the crowding of construction works such as buildings and bridge piers into the bed of the river so as to take up space necessary for the flow of flood waters. This has been the cause of many bad catastrophes in the past. In many of such cases there has been a rise of the water higher than in preceding years and it has been attributed to a greater flood; whereas, in reality, the real cause of the greater height has been due to the great constriction of the channel caused by encroachments built by man in such manner as to prevent the escape of the water.

The straightening and enlarging of a river bed will permit of the more rapid discharge of flood waters, but when this method is adopted for the upper portions of a river it simply transfers the flood problem from the upper river to the lower river. The flood control problem of any particular locality can only be solved by a comprehensive study of the entire watershed of the stream under consideration. It is rarely the case that a flood control problem is not of more than local importance, for what will help one locality is very likely to hurt another, and what is good for one place may be not at all helpful in another place.

ECONOMIC ASPECTS OF OUR TIMBER SUPPLY

By Colonel W. B. GREELEY

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ON Chesapeake Bay, just below the city of Baltimore, an enormous yard has been established for storing and distributing lumber manufactured on Puget Sound. As you watch the unloading of a steamer at this yard, jump in your mind across the continent to the sawmill where it received its cargo, follow its 6,000-mile course through the Panama Canal, and you will readily grasp

the leading factor in the lumber business of the United States at the present time and the controlling factor in its future provision of timber, namely, transportation. These lumber ships docking in Chesapeake Bay are not laden with cabinet woods or with timber of special and distinctive value. Their cargoes contain a large proportion of framing, siding, flooring, of the grades of lumber used every day in the construction of dwellings and for the more common industrial purposes. At Chesapeake Bay you may see this lumber transferred to freight cars for reshipment to points all through the Middle Atlantic states. Some of it is shipped inland as far as Cincinnati and Pittsburgh.

The factor of transportation dominates our forest situation. At the time of the Civil War, lumber manufacture was a local or at least a nearby industry in every state east of the Mississippi River. One hundred or two hundred miles marked the limit of ordinary lumber shipments from the sawmill to the market. A dollar or two a thousand feet covered the freight on the lumber of everyday use. And then with the tremendous industrial development of the 70's and 80's came the enormous sawmill, the concentration of lumber manufacture in particular regions, and its gradual movement to the west and south. With each successive outward "trek" of the sawmill, transportation has become a more important factor in the lumber business. About every twenty years, the center of lumber production has shifted to some new region still farther away from the largest centers of lumber consumption; and the freight paid on the average carload of lumber has reached a higher level. The cost of lumber transportation, either as a yearly total or on the average thousand feet, is the true barometer of the depletion of our virgin forests. Furthermore, the cost of transportation from the manufacturing region which furnishes the bulk of the lumber supply for any given market, at any given time, has to a very important degree controlled the general level of lumber prices.

To-day the big sawmilling industry of the country is dropping behind the Rocky Mountains. Washington and Oregon have become the two leading lumber-producing states. Within another decade it is doubtful if the pineries of the south will be an important factor in supplying the markets of the twenty-eight states which have become lumber importers. Eastbound lumber shipments from the west coast, by rail and by water, are increasing rapidly. Ten or fifteen years hence that region, which contains two thirds of the virgin saw-timber remaining in the United States, will apparently be our only large source of softwood lumber for the general trade. Already the cost of transportation from the

west coast is becoming a factor in the retail lumber markets of the eastern states.

The lumber movement in 1920 exceeded two million carloads, with an average haul of 485 miles. Lumber freights and charters reached a total of $275,000,000, which represents between $8 and $9 per thousand board feet on the average shipment. A large part of the lumber consumers in the United States are paying more for freight to-day than they paid thirty years ago for the commodity delivered at their doors. Many users of general construction lumber in the central and eastern states pay more for freight than this product is worth at the sawmill where it is manufactured.

It is not difficult to put in concrete terms how the rising cost of transportation has influenced the large eastern and central lumber markets. Take Chicago as an example, the greatest lumber mart in the world. Roughly, two billion feet of lumber enter Chicago every year. Thirty years ago its supply was drawn chiefly from the central and lake states, at a freight rate into the city of less than $3 on the average thousand feet. In 1921, the great bulk of Chicago's incoming lumber was manufactured in the far south or the far west, and the average freight had risen to $13 per thousand feet. In other words, rising transportation costs have taxed this lumber market $20,000,000 a year. A study of lumber shipments into New York, Pittsburgh, Detroit or any other of the large eastern consuming and distributing centers tells a similar story. Old lumber exporting states, like Pennsylvania and Michigan, now pay from fifteen to twenty million dollars yearly in freight bills on the forest products which they are compelled to import. The cost of lumber transportation has steadily become a more and more dominant factor in the principal lumber markets of the country and hence in the quantity and character of lumber consumption.

The Great Plains and the Panama Canal now separate our only large remaining source of softwood timber from four fifths of the population and nine tenths of the manufacturers in the United States. We are entering a period in the lumber business in which the transportation factor will be even more dominant than hitherto. And just as far as we can look ahead, its domination grows. When the virgin timber of the Pacific Coast is exhausted, the softwood forests of Siberia may become a controlling competitive factor in the lumber markets of America. Again the transportation cost will mount to a higher level and freight bills will weigh even more heavily in the retail price of lumber.

In other words, the amount of standing timber which we have left is much less important than its availability, as expressed by the

cost of getting it in manufactured form to some consumer who wants it. Large quantities of timber in inaccessible mountainous regions of the west will not be active in supplying our markets for forest products for a long time to come because of the excessive cost of transportation, in the log and in manufactured form combined. They are not available. Indeed, they may follow the timber of Siberia in supplying the markets of America and influencing its prices on forest products, just as our western pulpwoods are following the pulpwood resources of eastern Canada in supplying the American paper trade. In short, the volume of timber remaining in the United States, the twenty-two hundred odd billion feet of merchantable saw stuff which we estimate we still have, is not, after all, the most important factor in supplying our requirements in forest products. It is secondary to the cost of transportation, which mainly controls the retail price levels and consequently determines when the stumpage of any particular region can enter the principal lumber or paper markets.

It is not true to the mark, however, to visualize our future timber supply as readily obtainable within a constantly widening circle of transportation costs as long as the consumer is willing to pay the freight bill. The United States hitherto has enjoyed undisputed control of all the standing timber it could possibly use, with the exception of small quantities of semi-precious or other specialty woods. Foreign competition for the products of our mills has been negligible in volume and without effect upon market prices for forest products. It has been within our political power to eliminate it altogether whenever we chose. This same condition will hold true for the duration of the softwood forests of the Pacific Coast as the mainstay of the national lumber market, although it is worthy of note that oriental competition for timber from these forests bids fair to become by no means a negligible factor in volume as well as a subject of political discussion.

Once, however, we are compelled to go beyond the United States for any important percentage of our forest products, we shall encounter worldwide competition, and the story will be a different one. The pressure of population and modern civilization upon natural resources has no better illustration than the present worldwide situation as to supply and demand for coniferous timber. Mr. R. Zon's exhaustive survey of the forest resources of the world has shown that the accessible coniferous timber of the world is not adequate to meet the requirements of the twentieth century. Once we have to look beyond our own borders for forest-grown material, on a large scale, we must compete with world markets that are short of raw materials for paper and construction lumber.

International competition for forest products will certainly grow more keen as time goes on rather than less. The Forest Service has received inquiries representing Norwegian, British and Japanese capital looking to the establishment of paper mills in Alaska. The industrial growth of nations the world over has been signalized by a sustained increase in the consumption of paper and usually by a period of rapid advance in the consumption of lumber. Similar demands for forest products normally attend rising standards of living in any nation or increases in its purchasing power. The Chinese now consume about one tenth of a pound of paper per capita annually, the Russians about 6 pounds per capita, and the Japanese about 11 pounds per capita, as compared with 44 pounds in Germany, 75 pounds in England, and 149 pounds in the United States. The potential consumption of paper and lumber by the populous nations of Asia and eastern Europe, once their commercial development really gets under way, might well overwhelm the timber supply of the world within their reach.

In other words, when our own western forests are depleted to the point that we must penetrate into Asia or South America bargaining for timber, we will encounter far more than a new level of transportation costs. We will be met with stiff worldwide competition which is certain to establish price levels for lumber and paper in the consuming markets of the United States beyond anything we have hitherto experienced.

Now it is almost axiomatic that the transportation cost into any lumber market from the region which furnishes the bulk of its supply, once that cost is fairly established, is translated into higher stumpage values on locally grown timber which enters the same market. Anything that runs up the price of lumber or paper, like competition between different consuming regions, tends, if reasonably stable, to make what standing timber there is locally available worth more. The stiffer the competition New England encounters in stocking its lumber yards from the Gulf or the West Coast or from Siberia, the greater will be the price differential in favor of her own second growth stumpage.

Many elements of course influence the movement of stumpage prices. But in a broad way, underlying the general rise in stumpage values in all forest regions during the past thirty years, the effect of rising transportation costs on lumber from more and more distant sources is discernible. It is particularly striking in the case of second growth softwoods in regions accessible to large industrial centers, material which produces no specialty product and satisfies no high-grade demand but which must compete in the general market for low-grade construction or industrial uses. In new regions containing large supplies of virgin softwood tim-

ber, during any given period, the increase in stumpage values, while usually well sustained, has been relatively slow. But in almost every instance where enough second growth has been produced in old regions to become a factor in the lumber trade, its stumpage price has advanced at a much faster rate.

Extensive cutting of second-growth white pine in the New England states began about 1900. In the following twenty years the average stumpage value appears to have advanced from around $4 per thousand feet to nearly $10 in Maine and to $16 or more in Massachusetts and New Hampshire. In extreme cases second-growth New England pine has brought $25 on the stump, a price as high as that obtainable for old-growth white pine stumpage in the Lake States. A similar story may be told of the portion of the southern yellow pine region which was first extensively cut, the coastal plateau belt extending from Maryland through North Carolina. In the last ten years second-growth pine in this region has climbed in value, on an average, from about $3 to at least $7 a thousand feet. During the war its average price reached $9 and individual tracts were sold for as much as $14 a thousand.

The cost of transportation from a more distant source of timber has created these stumpage values for locally produced second growth. The same factor has accelerated the increase in stumpage values on virgin timber in each of the main forest regions of the country toward the end of its period of active exploitation. When the main source of all-purpose softwood lumber shifted from the Lake states to the southern pineries, the stumpage still left in the Lake states profited by the freight differential between that region and the new region, which rapidly dominated the old markets. The same thing is traceable in southern yellow pine to-day, with the gradual shift of the main source of our all-purpose softwood lumber to the far west.

I have purposely taken illustrations from the class of material which is consumed in the largest quantities and which consequently reflects the most general and stable basis of timber values. Illustrations far more striking could be taken from second-growth hardwoods which supply limited and specialized markets and also from wood entering into the manufacture of paper.

The broad application of the creation of higher local stumpage values equivalent to the differential in transportation costs to our future timber supply is obvious. Region by region this process leads inevitably to a point, some point, where plan-wise timber growing becomes commercially feasible and is well-nigh compelled by purely economic forces. The shifting of our principal source of softwood lumber to the west coast is setting a new price level in favor of locally grown stumpage. Lumber charters from Puget

Sound or the Columbia River through the Panama Canal to the upper Atlantic Coast seem to have settled for the present at between $15 and $18 per thousand feet. That differential in favor of competing timber grown in the northeastern states is certain to exert a powerful commercial pressure for timber culture.

Next to the transportation situation, the question of outstanding importance in relation to our future provision of timber is the amount of land that will be available for growing it and to what extent timber culture must compete with other forms of land use. Four hundred and seventy million acres of land, about one third of the soil of the United States, is now in forest, cutover land or abandoned farm land that once supported timber. The belief has been common that this acreage of actual or potential timber-growing land would be steadily whittled down by the extension of agriculture. As a matter of fact the tide of land clearing for cultivation ebbs as well as flows. The total acreage of improved farm land in the country has increased steadily from census year to census year; but in many regions it has been decreasing as a broad trend during the past four or five decades. Between the last two census years there was a net increase in farm acreage of 28,000,000 acres, but in nineteen states embraced mainly within the original forest belt east of the Mississippi River, the acreage of improved farm land decreased and in six other states it remained stationary. New England lost 32,000 farms during this period, with a net decrease of over a million acres under tillage. As a matter of fact, the increases in our national acreage of improved farm land are now coming from the regions which were never forested. Within the original forest belts of the United States, the net acreage of cultivated land is shrinking. The area of potential timber-growing land is increasing. The abandonment of more hill farms bids fair to at least offset the clearing of fertile valleys still in timber or stumps.

From what the farm economists prophesy as to the future trend of agricultural development in the United States, the abandonment of farms in timber-growing regions is apt to be accelerated rather than diminished. American agriculture is going through a terrific shaking down. Its leaders preach the gospel that success lies in concentrating farm labor and farm capital upon the most fertile and most favorably situated soils; that instead of producing our wheat crop at the rate of 13 bushels to the acre we should produce it on half as much land at the rate of 30 bushels per acre, with a corresponding increase in intensity of fertilization and cultivation. The drive for scientific farming, the use of better machinery, the putting of agriculture to a business test of profit and

loss are all tending to concentrate agriculture upon the more productive soils in the more favorable situations for access to market. The poorer and rougher and less accessible lands are going to drop out, the acres close to the profit-and-loss line will be thrown into the discard.

If this conception of the future development of American agriculture is sound, timber culture is not going to meet much competition in the use of at least one third of the land area of the United States. Other forms of land use, such as the rearing of livestock, will of course enter the competitive field to some extent. But it seems to be a reasonably safe prediction that the tendency for another generation at least will be to adjust the economic status of at least one third of our soil to timber growing as its principal crop. This will mean a gradual adjustment of the value of land of this character to the profits obtainable in growing timber. The adjustment of taxes on such land to timber growing as its principal crop will follow almost inevitably. Timber growing may indeed compete successfully for considerable areas of land that have a marginal value for farm crops just as it has done not infrequently in countries of the Old World. But the fact that we are likely to have four hundred seventy million acres, more or less, of land that will be largely without a crop unless timber culture gives it employment is an economic factor of the first importance in relation to our future supply of forest products.

There remains what doubtless is the most crucial point of all, namely, the probable demand for timber products. The United States has already passed through a cycle of rising and falling per capita consumption of lumber. From 345 board feet in 1870 it rose to 516 in 1906 and dropped to 316 in 1920. While the World War was largely responsible for the more recent and more abrupt portion of this decline and while the per capita consumption of lumber will doubtless rise when economic conditions permit satisfying the current demands for housing and industrial construction, nevertheless the drop in per capita use of lumber from the peak of 516 board feet in 1906 indicates a normal reaction arising from the higher cost of lumber and from the slowing up of new settlement and new industrial developments in their ratio to population. The reduced consumption of lumber also reflects the substitution of other materials where wood was formerly used, by reason of their lower cost or their better adaptation to construction requirements particularly in large urban centers. A large substitution of coal, oil and electric energy for fuel wood, which still forms 40 per cent. of the forest-grown material consumed in this country, has already taken place and is bound to increase.

Some of my associates who have given this matter the closest study estimate that with a present yearly consumption of twenty-two billion cubic feet of standing timber for all purposes, the substitution of other materials for wood is taking place at the rate of something less than one half billion cubic feet annually. Higher levels of lumber prices doubtless will accelerate such substitution as well as reduce the consumption of forest-grown materials where no substitutes take their place. I anticipate that when the bulk of our western coniferous forests have been put through the saw-mill and the United States becomes partially dependent upon foreign sources of timber for a considerable period until new crops of wood can be grown on our own land, there will be a material and enforced drop in per capita consumption. But as long as the United States retains its dominant characteristics as an industrial nation, there is bound to be an active demand for wood in one form or another that can not long be repressed and that is bound to obtain wood by growing it at home or shipping it in from abroad within any reasonable limits of cost.

A large part of our present consumption of wood is industrial consumption, material that does not go into the primary requisites of housing and fuel but into manufactures of one sort or another. The sharp advance in the per capita use of lumber in the United States prior to 1907 reflected the tremendous increase in lumber use for manufacturing purposes, railroad building and the like fully as much as the demand for more buildings. The per capita timber requirements of the nations of Europe which are advancing industrially are increasing, not diminishing. This has been very plain in the history of Great Britain during the last seventy years. It is bound to be true of the United States where the industrial use of wood has attained a greater volume and variety than in any other nation, where new products and processes involving the use of wood have come thicker and faster than in any other part of the world, and where living standards involve a dependence upon forest products to a degree nowhere else attained, as, for example, in our consumption of paper. It seems to me a reasonable conclusion that while the per capita use of wood in the United States will doubtless decrease still further, and while our total consumption of forest products may drop sharply during the period of readjusting the source of timber supply from virgin forests to second growth, yet in the long run there can be no material reduction in the present aggregate demand for wood at a price level sufficient to make timber growing commercially feasible on the greater part of our non-agricultural lands.

The United States now consumes, including its exports, about twenty-two and one half billion cubic feet of timber annually, or

about 212 cubic feet per capita. This includes fuel wood, pulp wood, railroad ties, fencing, mine timbers, etc., as well as lumber. We have at present four hundred seventy million acres of forest land or potential forest land, a figure not apt to be greatly reduced by the extension of cultivation. In the light of European experience it seems reasonable that this land area, averaging bad acres with good, can produce under intensive forest practice the equivalent of 58 or 60 cubic feet of wood annually. That would make the yearly production for the entire country twenty-seven billion cubic feet, with a leeway of about five billion cubic feet over present consumption. Timber growing is practically without a competitor in the use of this land. Already the rising transportation costs from distant forest regions have brought portions of this land, particularly in the northeastern states, into use for growing timber under intensive methods. Every year the still rising cost of transportation, with its reactions upon public policy, tax laws, fire protection provisions, etc., will widen the acreage of land used for growing forest crops under more or less intensive methods. It is spreading over New England and the Middle Atlantic states. It is creeping down the Atlantic seaboard. It is making gains on the gulf Coast and in the Lake states. Even on the Pacific Coast, where virgin timber is still plentiful and cheap, systematic timber growing is beginning at exceptionally favorable points, like the redwood belt of California.

Forestry is not wholly a matter of cold economics. The northern races of the world were forest-bred. The forest gave them their Christmas trees, open wood fires and love of the chase. The sentiment for forest preservation and forest growing is instinctive. The forward nations of the world have been quick to recognize the public interests jeopardized by forest destruction and to safeguard them by legal principles which transcend the *laissez-faire* doctrine of political economy. And the people of the United States, who lead the world both as users of wood and as lovers of wild places, can least of all afford to view their forest problem solely as an equation of supply and demand.

Nevertheless, there must be and there is solid economic ground for timber growing, with reasonable backing in public policy, as a permanent form of land use on all fours with scientific agriculture. It is fruitless to try to put the whole puzzle together at one sitting. No one can lay out an orderly plan, according to economic formula, for shifting our source of timber from the supplies stored up in virgin forests which are sought and mined out in the order of their accessibility, like coal deposits, to successive timber crops grown in the thirty-nine states which contain large areas of forest land. Yet in a broad way this is exactly the change that is coming

about, and as far as our present experience goes, putting the consumer's money into growing trees in his own state instead of transporting lumber from sawmills 2,000 or 3,000 miles away will shift the source of supply from a temporary basis to a permanent one, without materially increasing the cost of forest products to the user and without necessitating any permanent reduction in our use of wood.

STATE POLICY IN FORESTRY

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THE practice of forestry involves the curtailment of present revenue or makes present expenditure for the sake of future return, and this return may be fifty or sixty years hence. It follows, therefore, that only those institutions which are stable and which can look ahead to the future with a certainty of existence can afford to practice forest management to the highest degree of perfection.

It is the corporate community, whether the body be called nation, state or town, that has this necessary stability. The individual citizen lives but a short time, and wishes to secure the greatest satisfaction to himself during his life. He is necessarily selfish, ready to neglect the interests of his neighbors, and still more the interests of the future citizen.

If the private land owner practices forestry he must be inspired by motives more or less altruistic. The attitude of the individual, however, as pictured above, need not be that of the lumbering or pulp-making corporations, for they should look forward to a span of life greater than that of the individual and should be interested in perpetuating their business, provided that such forest control is not wholly incompatible with the earning of a present reasonable profit on their invested capital. Furthermore, there are returns that come to a community from the practice of forestry where the revenue can not be figured in dollars and cents. These returns may be of little value to the individual woodland owner, but they are vital to the community, and, therefore, it is the community that must make the investment that will assure them.

In Europe it was the towns and small communities that started the practice of forestry, because in the seventeenth and eighteenth centuries these communities were the most stable organizations of

government. States and empires were founded and swept away with kaleidoscopic rapidity in those unsettled times, and one could not expect an established policy so necessary to proper forest administration to come from king or emperor. It was only after political chaos gave place to some degree of order and permanence that state and nation in Europe gave thought to state forests and state forest policy.

In the United States there are five agencies for the practice of forestry—the federal government, the state government, municipalities, corporations and individual landowners. It was more or less inevitable that forestry in this nation should start with the federal government, not because it was necessarily more stable than the state governments, but because it was better fitted to take the lead, and we have surrendered to it all matter of scientific research and forestry started in this country as a matter of scientific inquiry. Furthermore, it had on its hands millions of acres of public forest lands that were greatly in need of proper management and so was able to go into the forestry business extensively, with almost no expenditure of capital.

The question may arise whether the second stage of development should lie with the states, or with the towns or how far private interests can be relied upon to give us that forest management that we must have. As far as individual interest lies in the same direction as community interest, so far should individual owners be relied on. As far as the interest of the town is visible so far the town should be left to manage its own affairs, but these are matters in which the interest of the individual diverges from that of the community, or else these are matters and interests so large that the smaller community can not afford to take care of them. Then it becomes the duty of the larger aggregation, the state, to step in.

The town is permanent, yet in the average American municipality you will find the tendency to live in the present with small regard for the future. Furthermore, the rural towns that have the largest forest area are generally poor, unresponsive to new ideas and are less likely to take up a forest policy in an adequate way than those more thickly populated.

It is not our intention, however, to throw cold water on the town forest idea, but simply to show that from the economic standpoint no large results can be expected for a good many years. If, however, the sponsors for town forests realize their limitations and rely on them merely for their educational value, their possibilities for recreation and as only one more step in the program of sustained forest management, they will prove of great service.

It seems, therefore, that we must look to the state for the next significant advances in forestry. The two most essential conditions needed for the practice of forestry are a rational system of taxation and protection from fire. The first can only be provided by the state because it is the body that makes the laws for taxing real property. The second (fire protection) must either be provided by the state or by the town, or both in cooperation.

It is quite evident that the federal government with one hundred fifty million acres of national forests has a large fire protection problem of its own. I am even skeptical of the wisdom of the present system of subsidizing fire protection on the part of the federal government, for it seems to me that each state should at least take the responsibility of protecting the property of its citizens without being assisted by the national government to perform this duty. It may be justified at the present time, but as a permanent policy, I question its advisability. Massachusetts has found by experience that in all such cases of federal subsidy it pays a large part of the bill and gets but a small rebate in return. When it comes to fire protection within the state, however, the state must lead and cooperate with the municipalities, especially the smaller ones and directly and indirectly render them financial aid, for, as has already been explained, those towns that have the greatest forest area are the least able to give that area adequate protection.

I do not think that there is any opposition on the part of the residents of our cities to the expenditure of a small part of their tax money for protecting the forests in the rural towns, for they realize that the interests of the whole state are their own. It would not be easy, however, to convince them that they should contribute towards forest fire protection in Georgia or California. On the other hand, I believe that the state should not assume the whole direction and cost of fire protection, for to do so would take away the feeling of responsibility for fires on the part of the people of the towns.

We find that in spite of the feeling about home rule, many towns are only too ready to surrender it when there is an offer of financial assistance. Most of our rural towns already receive aid towards schools, libraries, roads, moth suppression, pensions, etc., and a state aid policy if carried too far may result in the creation of a lot of municipal paupers with all the faults that we ordinarily associate with the individual poor. Cooperation and aid in the direction of self-help seem to us the proper policy in fire protection, even though for the moment the results are not up to an ideal standard.

When it comes to the third great problem in American forestry, the rehabilitation of our millions of acres of logged-off idle lands, there is bound to be considerable difference of opinion as to the relative parts to be assumed by nation, state, municipality and private owner. We can safely assume that the problem is large enough to require the combined efforts of all four. The national government already has the forests that came from the public lands and has several million acres purchased under the Weeks Law fund. This policy should be continued, but it should be confined to those sections of the country where the state and private effort is manifestly inadequate to handle the situation. The available territory is large. I personally discouraged the idea of a national forest in this state because it would be difficult to get a tract of sufficient size and also because I felt that this state should of all states be able to handle its own forest problem. When it comes to the division of responsibility between state, town and private citizen for forest culture, it will be found in the end that the state and the private owner must assume most of the burden. In spite of the publicity given to the "town forest idea" no great results can be expected from it simply because those towns that are financially able to establish forests have not the available territory and those that have the land haven't the capital to invest. The state must take the lead in reclaiming waste and idle lands because by the very absorption of a portion of these lands on the part of the state the capital value of the remainder is raised to a point where the private owners of waste land can afford to invest money in its improvement.

Contrary to prevailing opinion, too low a valuation on land is not an incentive to good forest management. When forest land can be bought and is assessed for $5.00 per acre, a very meagre crop pays the interest and taxes on such a valuation. Of course one can see the other extreme where land valuation is so high that no forest crop can pay taxes and interest. Personally I believe that a basic land value of $10 per acre means better management than five-dollar land. Assuming that there are 700,000 acres of waste and idle land in Massachusetts, I think the state will need to absorb about one third of it before private effort begins seriously to take hold of the remainder.

The most optimistic believer in our state forests does not promise that they will ever provide all the forest products that Massachusetts requires. There are certain pulp and lumber companies that own large tracts of forest land. These companies do not by any means cut their entire supply of logs on their own lands. In fact, their policy is when timber is cheap to get their supplies from

the land of others and save their own, but when prices advance they cut their own timber. It would be most fortunate for the wood-using industries of Massachusetts if they were the possessors, through the state, of such a reserve supply of timber. Just how much of the forest area of Massachusetts the state should own in order to have a workable timber surplus it is difficult to estimate, but probably not less than 10 or over 20 per cent. of the forest land.

Besides providing a timber surplus account to apply towards the depreciation of our private forests as a whole, state forests offer other returns in the form of recreational opportunities. Opportunities for camping, hiking and other outdoor activities can be provided without the slightest interference with the administration of the forests from the economic standpoint, and even the protection of certain scenic features can be carried out with but slight disarrangement of utilitarian management. State forests fit in most admirably with the program of the sportsman, for they offer on the one hand opportunities for game protection and propagation, and on the other hand a place to hunt and fish without meeting the forbidding posters now so common on private lands.

With proper fire protection, an insurable fire risk, rational taxation and absorption by the state of the surplus idle land in the form of state forests, I believe that private forest owners will solve our Massachusetts forest problems. Add to this free advice as to forest management, low cost of nursery stock, free of cost to towns for municipal forests and cooperation in marketing forest products, and I believe that you have an adequate forest program for a state with the conditions that exist in Massachusetts.

In connection with this paper, I read an article by the father of American forestry, Mr. Fernow, written for our State Board of Agriculture in 1902, entitled "A forest policy in Massachusetts."[1] He summarized his recommendations as follows:

1. Improvement in forest fire laws, making them general and under state supervision and cooperation.

2. Appointment of a state forester.

3. Encouragement by financial aid of all associations and educational agencies concerned in creating an active interest in forestry.

4. Acquisition by the state for forest reserves of those stump and brush lands that by their location and condition are of importance to the welfare of the state and do not promise to private enterprise sufficient inducement to care for them.

5. Establishment of nurseries for the distribution of stock at cost.

6. Encouragement to towns to acquire forests, the state to loan towns money for the purpose.

7. Encouragement to private owners to improve their woodlands by furnishing expert advice and by providing a just tax law.

It is interesting to note that twenty years later all of these recommendations except the third, which is constitutionally prohibited, have been carried into effect, a tribute either to Mr. Fernow's ability as a prophet or to the intelligence of a state in following good advice.

THE ECONOMIC IMPORTANCE OF WILD LIFE

By Dr. E. W. NELSON
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THE conservation of wild animals and birds is not a mere fad indulged in by those who have only a sentimental interest in the subject. It has a much greater importance, due to values difficult to measure but none the less real. Wild game especially is often of direct economic value to the inhabitants of a region, not only as food but also because of the expenditures of hunters and others attracted by its presence; and the recreational and educational advantages arising from an abundance of wild life in general are incalculable.

Recent investigations reveal the fact that in the aggregate wild life resources, capitalized on the basis of a 6 per cent. annual income, represent an enormous sum, possibly exceeding $1,000,000,000, and through intelligent management are capable of a great increase.

The game and wild life of this country thus form the basis of extensive commerce in the preparation for the harvest of the annual crop, which is of great value from several points of view but mainly in supplying a highly prized form of food; as affording sport to a multitude of men and employment to others; and as a source of renewed health and vigor to numberless men attracted by it to a period of vigorous life in the open each year. The number of wild animals killed each year in the United States is not definitely known, although several states have at various times compiled statistics on the subject. The necessity for fuller information concerning the annual kill becomes of greater importance when the ever-increasing number of gunners and trappers, with their improved devices for capture and means of transportation, are taken into consideration, to the end that the capital stock may not be diminished nor the annual dividend therefrom reduced.

In 1921 there were approximately 4,500,000 licensed hunters in the United States, and the number hunting on their own lands without license was estimated at approximately 2,000,000. The returns to the various states from the sale of licenses and other

sources of income aggregate approximately $5,000,000 annually which is spent mainly in the work of guarding, propagating and maintaining the breeding stock and increase of wild life for future seasons. Every state of the union except North Carolina, Florida, Mississippi and Nevada has a special agency charged with the duty of looking after the wild life resources of the commonwealth, and wardens are constantly employed in the statewide work of staying the transgressor of the conservation laws, and in feeding and otherwise conserving the wild life.

The decrease of wild life with the advance of settlement and occupation of the land by man and his domestic flocks and herds was inevitable. It is a blot on our custodianship of the wild life of the country, however, that commercial slaughter should have been permitted to the extent that the supply was ruthlessly wasted, both as regards large and small game and game birds. The classic example of big game destruction is furnished in the case of the buffalo, which roamed in countless numbers in the days of the aborigines. In the case of game birds, the myriads of passenger pigeons brought to absolute extinction by the pot hunter also furnish a striking example. Civilized man and his inventions have become a menace to wild life throughout the world.

The wild game and fur bearers of the land had a wonderful part in the upbuilding of this country from the arrival of the earliest colonists through the era of exploration and settlement, through the period of construction of the transcontinental railways and even to-day is vital to the existence of miners and others in remote parts of Canada and Alaska.

The Buffalo

After the construction of the first transcontinental railroad, commercial companies were organized to gather the bones of the buffalo slaughtered in part for the subsistence of the great construction gangs employed in its building. Some idea of the magnitude of the operation may be gathered from the reports of a single railroad—the Atchison, Topeka and Santa Fe.

The traffic in bones and buffalo products from the Great Plains region are recorded by Dr. Hornaday in his report published in 1887 on the extermination of the American bison. There appears to be good ground for the belief that the statistics furnished by this one railroad represent only one third of the entire buffalo product. It is therefore in order to base further calculations upon these figures. According to evidence gathered on the spot during the period of the great slaughter, one hide sent to market in 1872 represented three dead buffalo; in 1873 it represented two; and in 1874 one hundred skins delivered represented 125 dead animals.

The total slaughter of buffalo by white men in three years, 1872-74, may be approximated on the foregoing basis, with a knowledge of animals actually marketed. Railroads reported shipments of 1,378,359 hides; this would mean an additional 1,780,461 animals killed and wasted, or a total slaughter of 3,158,730. The rapid extermination is shown by the fact that approximately 3,000,000 of these animals were about evenly divided between the first two years, while in the third year there were only 158,583 so slaughtered. The Atchison, Topeka and Santa Fe Railroad also reported that during the same three years 2,250,400 pounds of buffalo meat and 10,793,350 pounds of bones of these big animals were shipped over its lines.

After the great slaughter of 1880-84 the buffalo was practically exterminated as a wild species. A census of buffalo taken in 1889 showed only 1,091 animals wild and in captivity in the United States and Canada.

Game Birds

With the extermination of the buffalo began the development of the great markets for quail, grouse and wildfowl in Chicago, New York, St. Louis, Boston, Philadelphia, Baltimore, Washington and other large cities, at first sanctioned by law and later supplied in defiance of the laws of the states from which supplies were drawn. The passage of the federal Lacey Act, in 1900, prohibiting interstate commerce in game killed in violation of the state law, aided materially in staying illegal traffic in game. With the prohibition of sale of migratory game birds under the Migratory Bird Treaty Act of 1918, game, except rabbits and squirrels and venison in a few places, has practically been taken off of the market. The fact that game is not now generally commercialized, however, does not depreciate the individual value of the game killed, although the total kill is greatly lessened, the channels of consumption having been diverted from the patrons of hotels and restaurants to the hunters and their friends.

Sportsmen who in many sections are enjoying good wildfowl shooting to-day now realize the conditions they would be facing were it not for the beneficial effects of federal laws giving protection to migratory birds. Federal prohibition of the sale of migratory game birds crowned with success the campaign led by conservationists of vision whose goal was to limit the killing of game to the field of recreation and sport. With the abolition of spring shooting, wildfowl conditions are again approaching those of two or three decades ago.

Other Big Game

Recent estimates of the total number of big game in the United States, other than deer, in 1920 are as follows: Buffalo, 3,400; elk, 52,000; antelope, 7,500; moose, 7,000; mountain goats, 6,000; mountain sheep, 10,000. This total of about 86,000 covers only the big game south of the northern boundary of continental United States, and does not include the game of Alaska or of any part of Canada.

It is of course impossible to estimate accurately the value of this big game. Some of the elk, moose and sheep belong to species found nowhere else in the world and are now represented by small herds. Unlike most things which have a definite value, wild game can not always be replaced when it is exterminated over an area. No market value in the ordinary sense of the word can be placed upon such animals. If buffalo should be valued at $200, antelope and moose at $100, elk at $75, and sheep and goats at $30 each (all conservative figures, at least for animals for propagating purposes), the total value of the big game, other than deer, would be not less than $5,000,000. Deer are much more abundant than any of the other kinds of big game, and with the figures available it is probably safe to estimate that their value is at least twice that of other big game, making a total value of at least $15,000,000 for all the big game in the United States, exclusive of Alaska.

Elk

Preservation of the elk in the Yellowstone Park and other regions will not only maintain a fine example of the great game herds which once frequented the west, but at the same time will perpetuate big game hunting on a considerable scale.

It is believed that these elk herds will prove such an asset to the states of Montana and Wyoming, where they will far exceed in value the returns from the livestock which would replace them if they were to be eliminated from the range.

Game Estimates

In any attempt to approximate the total value of the game killed annually in the United States, it is to be constantly borne in mind that statistics of the actual kill are not available for any considerable portion of the country. A few states have fairly accurate estimates of the number of deer and other big game killed over a considerable period, while in others the returns by licensed hunters form the basis of a fairly satisfactory estimate. Among the schemes for collecting data on the annual kill of wild life are those requiring reports by hunters, trappers or wardens, or those involving questionnaires to representative sportsmen in the differ-

ent localities of a state. Given a fairly accurate estimate of the kill, it becomes an easy matter to calculate the value of the game. A few only of the estimates available can be given owing to lack of time.

The state game and fish commissioner of Minnesota, in a paper read before the Tri-State Development Congress at Milwaukee, estimated the number of deer killed in the three states of Michigan, Minnesota and Wisconsin as follows: In 1919, 68,286; in 1920, 48,072; and in 1921, 37,500; or a total of 153,858 in the three seasons. At $30 each, the food value of the deer killed amounts to $4,415,740.

The total number of deer killed in 12 years in New Jersey, beginning with 86 in 1909 and ending with 844 in 1920, is 3,626; and in Massachusetts the number killed from 1910 to and including 1920 is 13,081.

Sixty years ago deer were practically exterminated in Vermont, and a few sportsmen in Rutland county secured 17 for restocking the county. After a closed season for a number of years the season was open on buck deer only in 1897, and in that year 103 were killed. A total of 4,440 deer were killed in the state in 1920 and from 1897 to 1920, inclusive, the total number, according to the records of the state game department, reached 44,286.

The value of the wild life kill in Michigan for 1920, including $3,000,000 for fur-bearing animals, was placed at $4,975,377; in Wisconsin, for 1921, including game birds at $2,333,000 and fur-bearing animals at $1,341,000, the total is $4,440,000; and in Minnesota for 1921, including 1,761,062 game birds and 631,140 fur animals, the total value of wild life killed is placed at $4,690,262. In 1920, the value of the game alone, including among other species 18,572 deer, 501,525 ruffed grouse and 1,414,889 wild ducks, was placed at more than $2,600,000.

In commenting on the statistics of game killed in Michigan, Minnesota and Wisconsin the Minnesota commissioner stated "it should be borne in mind that the figures represent merely the annual income from the permanent capital stock. Figured at 6 per cent. income, the capital investment on which we are collecting this annual dividend would amount to over $235,000,000 in the three states."

The game killed in New York in 1918, including 8,293 deer, 465,590 cottontail rabbits, 641,508 fur animals and nearly 250,000 game birds was valued at $3,239,277 by the conservation commission.

The total weight of the game killed in Pennsylvania was figured at 7,252,048 pounds in 1919, and in 1921 9,497,277 pounds. The game commission placed the value of the meat supply from the

1921 kill of game, on a basis of current food prices, at $3,500,000, and valued the furs taken in the state at $2,500,000, making the total annual value of the kill of wild life in the state $6,000,000.

Fur Resources

The fur trade, which was the forerunner of agricultural and other industrial developments, has now become one of the large and important industries in the business world, providing employment for thousands of skilled and unskilled workers and contributing to the comfort of people who wear fur garments. North America has been the leading continent in the natural production of furs and is also the greatest fur-consuming region in the world. Imports of undressed furs into the United States during 1920 were valued at over $84,400,000, and of dressed furs and manufactures thereof aggregated $9,131,000. Members of the national organization of fur dressers and dyers dressed during 1920 furs valued at $52,-910,589. The revenue derived by the federal government from the 10 per cent. excise tax on articles made of fur amounted to $15,311,214 in 1920. Exports of furs and manufactures thereof for this period were valued at $32,889,995. The approximate turnover in the fur industry of the United States during 1920 was $352,000,000.

Judging from reports and observations in the field, it is estimated that 500 ranchers are raising silver foxes in the United States, that they have more than 15,000 foxes in captivity, and that the value of the investment is about $8,500,000.

Alaskan Fur Resources

Through the cooperation of postmasters and commercial transportation companies in Alaska, shipments of furs by mail, express and freight are reported to the Biological Survey, which has jurisdiction over Alaskan land fur-bearing animals. It is estimated that the value of these furs will in ordinarily good years exceed one million dollars.

Fur Seals

In the report of the Bureau of Fisheries for 1909, the commissioner made the following statement (p. 29):

> If pelagic sealing could have been stopped in 1897, the seal herd of to-day would contain 300,000 breeding cows (as against 50,000, the number for the season of 1909), and the product of the hauling grounds would have risen to 50,000 skins, yielding a government revenue of $500,000, as against less than 15,000 skins and a government revenue of $143,000 for the present year. Without the drain of pelagic sealing the herd would continue to increase almost indefinitely.
>
> The Alaskan fur seals constitute the most valuable fishery resource that any government in the world ever possessed. It is little less than a national

disgrace that the herd of four to six million seals which came into our possession when Alaska was acquired from Russia and has been under our charge ever since should have been allowed to dwindle until to-day it numbers less than 150,000 of all ages. The mildest way in which to characterize the dissipation of this great resource of wealth of our people and of revenue to our government is that it is a serious indictment of our business capacity. The extent of our loss may be partially seen when it is stated that the failure to maintain the seal herd has during the last thirteen years resulted in a net loss of revenue of not less than $1,600,000, has permitted nearly 300,000 fur seals having a market value of over $5,700,000 to be appropriated by aliens, and has encouraged those nefarious pelagic operations by which additional fur seals having a value of at least $5,000,000 have been killed at sea, but not recovered; while through the slaughter of breeding females their pups—on the islands, unborn and prospective—with a potential value of fully $20,000,000 have been sacrificed and wasted.

Records of pelagic sealing carried on in Alaska under contract from 1870 to 1899 show 1,840,364 seal skins taken, from which the government derived a gross revenue of $6,010,565 and a net amount of $5,807,910, or an average of $3.15 per skin. Contract sealing was continued from 1890 to 1909, during which time 339,180 skins were taken, from which the government received a gross revenue of $3,752,415, netting $3,156,330, or an average of $9.30 a skin.

In carrying out the provisions of the seal fisheries convention between the United States, Great Britain, Japan and Russia, signed on July 7, 1911, the seal herd has been under the direct management of the Department of Commerce. From 1910 to July 1, 1921, notwithstanding a closed season of five years, which expired August 24, 1917, 101,594 skins were taken and marketed for a gross sum of $4,321,141.03, and a net amount of $3,169,544.53, or an average of $31.20. Of the net amount, however, $1,010,869.24 has been paid to Great Britain and Japan under the terms of the convention, and 41,091 seal skins remained on hand to be sold.

At the time the Pribilof Islands were first leased the herd was estimated to contain over 2,000,000 animals, but during the leasing period of 40 years it was depleted to 132,279 animals. From 1910 to 1921 the herd is reported to have increased to 581,453.

The following states have at one time or another placed a money value on their annual kill of wild life: Idaho, $1,000,000; Michigan, $4,975,377; Minnesota, $4,690,262; New York, $3,239,277; Oregon, $900,000; Pennsylvania, $6,000,000; Vermont, $502,000; and Wisconsin, $4,440,000, or a total of $25,746,916, in the eight states mentioned. Capitalized at 6 per cent. interest, this would indicate an annual dividend on approximately $430,000,000. Granted that a third of the wild life of the United States is found in the eight states mentioned, the estimate of $1,000,000,000 for the United States is conservative.

THE ECONOMIC VALUE OF PUBLIC PARKS AND SCENIC PRESERVATION

By Dr. GEORGE F. KUNZ

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PUBLIC parks and reservations—municipal, state and national—have several values, esthetic, educational, hygienic (which includes recreative) and economic. These values are so closely related and interdependent that it is difficult to separate them and to say where one ends and the other begins, for as a matter of fact it is the esthetic and the educational and the hygienic values that give them their economic value.

It is a mistaken notion that only the comparatively few cultured and highly educated people have esthetic appreciation of parks, reservations and places of natural beauty. Esthetic appreciation is a natural instinct and a very democratic possession. Where it does not exist it has been crushed out or suppressed by adverse circumstances. Children would rather play on the grass than on the pavement. They prefer a tree to a lamp-post or telegraph pole in their games. They instinctively pluck flowers if they can when they see them. They do not hesitate to stop passers-by who are returning from the country with wild flowers and beg a few blossoms. In everyone, from the child of the east side who plucks the flower in Central Park up to the mature and cultured traveler who revels in the glories of the Yellowstone, the Yosemite, or the Grand Canyon, the esthetic instinct exists as a natural craving that calls for satisfaction; and its satisfaction is one of the sources of the highest happiness.

Whatever gives happiness has value, although that value can not always be expressed in terms of dollars and cents; and yet frequently it can. In a residential district, a house and lot situated amidst neighbors who have unkempt and untidy dooryards and backyards is not as valuable in dollars and cents as one surrounded by neighbors who have attractive dooryards and backyards. Barren dirt house lots, with heaps of rubbish of all kinds, are a poor asset to the owner and neighbors; whereas grassy lawns, trees, shrubs, gardens and general tidiness are an actual economic asset to the whole neighborhood. Sometimes a single beautiful tree, or a single great rock, will make a place famous and add to its value. The same argument applies to public streets and public parks. A tree-lined roadway or a public park is a public asset, and by a public asset we mean an asset of the individual people

who compose the public. It enhances their pleasure and comfort and it enhances the value of the neighboring property.

The same is true of almost any natural feature within a town or its neighborhood. No matter how level and seemingly unpicturesque the region may be, there are almost always gullies or ravines, protected from the wind, in the bottom of which the flora and vegetation are more prolific than on the wind-swept upper levels. These gullies or ravines are often used injudiciously by the neighboring inhabitants as dumping places for garbage and refuse material. If, instead, the inhabitants would bury or otherwise dispose of their refuse, and keep the ravines clean and attractive, they would be transformed into parks and form an asset instead of a detriment to the community. An interesting illustration of the value of preserving glen scenery within a town is afforded by the Cascadilla Glen in Ithaca, New York. This beautiful ravine runs along the southern boundary of the Cornell University Campus. A few years ago the Cascadilla Company, including one of the public-spirited trustees of the American Scenic and Historic Preservation Society, Hon. Robert H. Treman, acquired an old mill and considerable property along the ravine, removed the mill, beautified the property, and conveyed to Cornell University all their rights in Cascadilla stream down to a certain bridge. A few weeks ago Mr. and Mrs. Treman conveyed to the university some lots near the bridge, permitting the removal of some houses and the opening up of a beautiful vista up the ravine and toward the campus. Such gifts and acts are fine examples of civic spirit: and they confer a lasting benefit on the community.

We may cite as an illustration of the economic value of a private park Gramercy Park in New York City. In 1831 Samuel B. Ruggles acquired from James Duane a farm of twenty-seven acres, including the present Gramercy Park and surrounding property. This farm comprised an area equal to about 108 city lots. Ruggles converted 42 lots into a private park and sold the 66 surrounding lots with certain restrictions and with the privilege of the use of the park. It was a wise piece of business, for the esthetic and hygienic value of the park of 42 lots enhanced the economic value of the surrounding 66 lots more than 100 per cent.

As an illustration of the economic value of a great city park we may cite Central Park. The great municipal park contains 843 acres. Back in 1838, when land was bought for the old Croton Reservoir, it cost about $2,316 an acre. Eighteen years later, in 1856, land for the park cost about $6,838, an increase in value of about 300 per cent. In 1863, the last purchase for the park cost about $18,147 an acre, an increase of 780 per cent. in 25 years.

The land for the whole park cost $7,389,727, and is carried on the books of the Tax Department as now worth $225,000,000, an increase over thirty fold (3,000 per cent.) in value. The foregoing figures refer to the land value of Central Park itself. The increase in the value of the surrounding property has been more than twice that rate. In 1856 the valuation of the real estate in the twelfth, nineteenth and twenty-second wards—all of Manhattan Island north of 40th Street—upon which there were comparatively few improvements, was $25,671,490. Ten years ago, the valuation of the same land without improvements was $1,941,787,550, while the valuation of the land and buildings was $2,888,306,240. The increase in the land value alone of the surrounding property, due largely to the presence of Central Park, was over seventy-five fold (more than 7,500 per cent.).

Let us now take some illustrations of great state reservations. The state owns in the Adirondack and Catskill forest preserves 1,992,516 acres of land. For the purchase of this domain the state has expended about $10,000,000. This figure includes $4,075,000 appropriated before the bond issue authorized in 1916, and about $6,000,000 thus far expended or contracted for under the bond issue. Six years ago, when only about $4,000,000 had been expended for land purchase, the area acquired was conservatively valued at $40,000,000. By a like ratio, the present forest preserve is worth about $100,000,000, or tenfold its purchase price. But that is not the sole measure of the economic value of the forest preserve. Its function in conserving the water supply is of inestimable value to the industries deriving water-power from the Hudson and its tributaries, and eventually it will be a source of wood for industrial use. The railroads, hotels and local interests also derive large revenues from the hundreds of thousands of visitors who seek the Adirondacks for health and recreation. Up to a few years ago the New York Central Railroad Company used to publish statistics of its excursion business due to the Adirondacks. These figures are not now available, but if known they would represent a very large figure.

Niagara Falls is a purely esthetic reservation of about 412 acres of land and water. The state paid $2,500,000 for it. It was not bought for any material purpose. It was acquired so that the people of the state and the nation, and of the whole world, might have free access to one of the sublimest spectacles of nature. The state itself derives no income from it, but the railroads, hotels and local interests find it of great economic value. It has been estimated that not less than 1,250,000 persons visit Niagara Falls each year, and it was formerly considered conservative to estimate that

each visitor spent about $20 on fares, hotel accommodations and other local expenditures. On that basis, the revenue on account of the scenic beauty of Niagara Falls could be reckoned at about $25,000,000 a year. At present rates, probably $30,000,000 or $40,000,000 is spent annually to witness the spectacle of Niagara.

The number of visitors to the Palisades Interstate Park exceeds that of the visitors to Niagara Falls, being estimated at 1,782,643 last year. This large number is due, of course, to the park's proximity to the enormous population of the metropolitan district. On account of that proximity and the relatively small expense of access to the park, the "economic value" of the park may not be as great as that of Niagara. But this illustrates anew how misleading it is to attempt to estimate the benefit of public parks by their "economic value." The economic value of the Palisades Interstate Park is represented, not by what people spend there and in going there, but by what is saved them on account of the inexpensiveness of the trip and by what they gain from going there. And here again we must emphasize the fact that the greatest value of these parks can not be computed in dollars. The recreation, the physical and mental refreshment which people get from the trip and the visit is their greatest revenue.

This is true proportionately of the six important state properties which the American Scenic and Historic Preservation Society administers—Philipse Manor Hall, Stony Point Battlefield, John Boyd Thacher Park, Fort Brewerton Reservation, Battle Island Park and Letchworth Park—to which there were probably 100,000 visitors during the year.

The movement for state parks has received a great impetus during the past two years from the two national conferences on state parks, the first held in Des Moines in January, 1921, and the second in Bear Mountain Park and New York City in May, 1922. The American Scenic and Historic Preservation Society has done a great work during the preceding 25 years in disseminating information on this subject throughout the country and in lending encouragement to the creation of public reservations in other states; and yet nearly half of the states have no state parks and many other states had only the beginning of a state park system. The national conference was therefore called for this intimate exchange of information and ideas and for the encouragement of the backward states in this important movement. The new state parks created during the past two years have largely been due to this national conference.

With reference to the creation of municipal, state and national parks, it should be noted in passing that except in desert regions,

scenery can not be preserved as natural scenery without trees, birds and other animals. Trees are the natural ornaments and protectors of the land; and birds and four-footed animals are the natural inhabitants of the woods. These are parts of a perfect scenery. If the trees along the roadsides and in the fields are preserved, the birds will come to them, and if the trees are thick enough and wild life is protected, the wild animals will seek their refuges there. These are all elements of scenic and educational value as well as economic value.

As to our great system of national parks, we gather some interesting figures from the reports of the National Park Service. In the fiscal year of 1921 there were 1,171,797 visitors to the national parks and monuments. The government spent about fifty-four cents per visitor for maintenance and administration—"about the cost of a good seat at a movie show," as the director of the National Park Service expresses it. Mr. Mather considers it very conservative to estimate that each visitor spends at least $100 on his tour. On that basis, the national parks represent a business of $117,179,700. And it should be added that the systematic development of our national parks is very young and their patronage in its infancy. A New York financial newspaper in 1915 estimated that the American tourist travel to Europe cost this country $500,000,000 a year. The more we cultivate the spirit of "seeing America first" and appreciating our own privileges, the greater will be the economic value of our public reservations.

The older European countries have long appreciated the value of preserving their natural and their historic monuments, and this work is carried on by such organizations as the National Trust in England; the Commission des Monuments Historiques in France; the Bond Heemschut in the Netherlands; the Staatliche Stelle fur Naturdenkmalpflege in Germany; and the Swiss Nature-Protection Commission in Switzerland. Within a few years, partly through the encouragement of the society of which I am president, the Society for Preserving Landscapes and Historic and Natural Monuments has been formed in Japan and a national law has been passed for the preservation of historic landmarks and places of exceptional scientific or scenic interest. Canada also has recently formed a landscape society, and the National Park Service of Canada has derived much encouragement and assistance from our society.

The American Scenic and Historic Preservation Society, in the course of its work during the past twenty-seven years, has published twenty-seven annual reports, comprising 10,850 pages of reading matter and 916 pages of illustrations, dealing with 39,634

names and subjects. The indexes of the last twelve reports contain 65,692 page references. These have been circulated all over the United States and Europe with valuable results.

The total known gifts of land, moneys, etc., by members of the society for public parks, civic improvements and historic preservation up to January 1, 1922, amounted to $6,181,419, and doubtless there have been many more of which we have no record.

The amount of gift funds expended by the society itself exclusively on public properties prior to January 1, 1922, was $57,256; the amount of gift funds expended by donors directly with the advice and cooperation of the society, but not passing through the society's treasury, $83,125; and the amount of state funds expended by the society exclusively on state properties without administrative charges, $282,819.

The society has been directly instrumental in the creation of eight state parks and one city park; partly instrumental in the creation of four other state parks including the Palisades Interstate Park; and indirectly helpful in the creation of still others.

These figures indicate the strength of the movement for scenic and historic preservation and also what one organization can do in promoting it.

There have been a number of instances where scenic preservation or beautifying has brought great financial return. One of the most notable of these instances is that of the Cathedral at Copen hagen. This cathedral was built in the outskirts of the city and was left in an unfinished condition for over a century, with the result that nothing but shanties and hovels surrounded it. Finally, a wealthy citizen of Copenhagen volunteered to complete the edifice at his own expense, provided he were given authority to proceed. The authority was given, he completed the cathedral, and not only paid for its completion, but incidentally cleared a considerable sum of money above the cost of the work, because he had immediately bought all the land in the vicinity of the cathedral, made a beautiful select section of it, and sold it for the finest residential property.

Another instance is that of the Buttes Chaumont in Paris. This chalk mountain was in the outskirts of Paris and was filled with pits and holes and was the abode of the most questionable characters during the French Commune. Gradually lakes were formed where there were holes, and the hillsides were set with trees, with the result that a splendid residential section now surrounds this formerly forbidding and dangerous region.

By the selection of important points that are frequently denuded and bare, and planting them with trees and bushes, a few

acres will frequently influence many hundreds of acres in creating a proper environment.

If, when the plans for the city of New York above 10th Street were being prepared, there had been a landscape architect, or someone with judgment, he could have used the various ponds for small lakes, he would not have eradicated every hill, but would here and there have given us a small park, and would not have laid out the city on the lines of a checker-board, with a loss of both beauty and accessibility, and instead of giving us few avenues and many streets, he would have reversed the order and given us many avenues and fewer streets, with the result that traffic would not have been rendered difficult for many years and almost impossible as it is today; moreover, as the sun rises in the east and sets in the west, it would have meant that two or three times as many homes as now would have had sunlight all day, whereas at the present time in many of the side streets the sun is never seen and the streets are filled with ice, and the death rate of the entire city has been notably increased by the little knowledge shown of what New York was to be in the future.

The setting aside of the area occupied by Central Park, 900 acres, at a cost of $40,000,000 has been a most profitable investment. One side, the east side of the park, is worth more than the cost of the park and the cost of the east side of First avenue, plus $1,700,000 or more. And the three other sides nearly double this accretion of value and we still have our Central Park.

ECONOMIC ASPECTS OF OUR NATIONAL PARKS POLICY

By ROBERT S. YARD

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SHALL we keep our national parks or shall we turn them into national forests?

For three years two organized bodies of Americans have been disputing before the court of Congress precisely that question.

One side seeks to destroy, the other to preserve, the complete conservation which, alone, from the beginning, has differentiated our national parks system from all other public reserves. It was Yellowstone, the first national park, that half a century ago defined the primary use of the great system which was to follow.

This primary use may be described sufficiently for present purposes by calling a national park a museum. Our national parks

system is a national museum. Its purpose is to preserve forever, "for the use and enjoyment of the people," certain areas of extraordinary scenic magnificence in a condition of primitive nature. Its recreational value is also very great, but recreation is not distinctive of this system. Our national reservations are also recreational. Our national forest, set apart for scientific commercial utilization, is very highly recreational. The function which alone distinguishes the national parks system from the national forest is the museum function made possible only by the parks' complete conservation.

The law has never clearly defined a national park. If it had, there would be no war to-day between the politically and financially powerful few who seek to break down the system's conservation, and the increasing millions who earnestly contend that the public policy of half a century shall not be destroyed for the profit of some local industrial interest, or of such interests in combination.

The law of 1916 creating the national park service defined its purpose "to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them (the parks) unimpaired for the enjoyment of future generations." Neither this nor other laws specify in set terms that the conservation of these parks shall be complete conservation, though this is the clear inference from the law quoted considered together with the organic laws of the individual parks from the beginning. The people's defense rests upon this inference and upon the public policy flowing from it. Complete conservation was intended by Congress and the nation as the particular purpose of the creation of the first national park of the system, Yellowstone. Its presumption took practical shape as soon as the Congress which created Yellowstone assigned it to the Interior Department for administration in March, 1872. Every Congress and every administration since has confirmed it, thus creating the national policy.

Those business interests which have labored so hard and so long, at so great an expense of time and money, to break down the protecting wall of complete conservation hold that the national parks have no economic value until their stores of water are producing cash revenues. They ignore the public policy of conservation, shouting that "eastern sentimentalism" alone is in opposition to their program of industrial invasion. By inference they assert that sentiment has no economic value.

But even these acquisitive gentlemen, I think, would freely admit that anything that makes strongly for the physical and mental health of the people, for pride of country, for the sanity of big horizons, for better comprehension of the needs and viewpoints of

distant sections of the country, for outdoor living, for travel, recreation and recuperation, makes powerfully for individual and national fitness to carry on and up the nation's material progress. All the money the nation possesses in public and private ownership could not purchase influences to accomplish such results if none existed, and surely no materialist has the temerity to deny them economic value beyond the possibility of price.

There is one element in the popular conception of our national parks system which I want especially to emphasize. That is its importance as a formal visible expression of the greatness and glory of this nation among the nations. Much of its value flows directly from this conception. The sentiment which brings the majority of the people so promptly to the defense of the system endangered is very far removed, indeed, from "sentimentality," unless national pride can be so termed. Were these parks in private or state ownership, or even in national possession but not set apart as a protected national institution, they would arouse nation-wide individual admiration, but they would not inspire a national enthusiasm.

In these enlightened days nature conservation is an American creed, but in no sense is it a fighting slogan. Defeating the spoilsman aroused the nation two or three decades ago as few reform movements have done, and we are still alert to crush public greed disguised as business. But neither of these causes, nor both combined, can in the least explain the eagerness and indignation with which the people in every state now rise at the mere word of warning in defense of their national parks system.

To one observing the popular state of mind from the center of this movement of defense, its essence is as clear as white light. There is no possibility of mistake. Two years ago the unannounced reading of national parks defense resolutions at the convention of the Daughters of the American Revolution brought instantly to their feet two thousand delegates representative of all the states. Even a labor convention in Chicago, plumbers, by the way, passed park defense resolutions and forwarded them to Congress. The defeat of the Walsh bill to dam Yellowstone Lake was not a defense of Yellowstone, but of the national parks system. These people are not fooled in the least by special pleadings. Piteous appeals for just one little reservoir in an obscure corner of one national park are unerringly understood to call for the building of many reservoirs in all the parks. The greatest protest, yet, that against Secretary Fall's proposed All Year park, is inspired by the certain knowledge that its many commercial precedents, if introduced into the system, will promptly infect all.

Why this intensity of protest? And why do millions join it who have never seen a national park and expect never to see one?

Simply because our national parks system has come definitely to mean to the people what, in kind at least, our flag means, namely, the majesty and pride of the nation. It is something extraordinary, inspiring, greater in quality and variety than the similar possessions of any other nation—and it is tangible, visible to all the world. Finally, it is idealistic in high degree, the concrete visible expression of a quality of mind and spirit which Americans believe that they possess in higher degree than any other people.

The American people insist upon their idealism. The fact that half a century of Congresses and governments, without any urging of the people until now, has safeguarded this system from all assaults upon its integrity restores their oft-shaken belief in our nation's essential righteousness and confirms the national faith in the form of representative government. This conclusion is no refinement of inference. It shines clearly in the expressions, crude or complete, which come increasingly to me from the plain people of all parts of our land.

To this audience there is no need of driving the argument home. The subject assigned me is "Our national parks policy in its economic aspects." It needs no elaboration to show that it is not the areas called national parks, majestic though many of them are, that mean this inestimable thing to the people, but the vitally significant creation which our national policy has built out of them. Completely conserved, with all that this implies, our national parks system is one of the inspirations to that pride of country and belief in its nobility which are essential to a nation's greatness and power. Its economic usefulness, therefore, is beyond computation.

Another economic value which our national parks possess in very high degree because of their conspicuousness and the eagerness with which they are studied both in the parks themselves and at home follows from their ability to convey scientific facts palatably to large masses of people. They are not only a national museum system. Their practical educational values are extremely high.

The parks in the system are nineteen in number, seventeen of which are within the United States, one in Alaska and one in the Hawaiian Islands. There are also twenty-six national monuments preserving objects or areas of archeological or special scientific value.

Of the seventeen national parks within the United States, fifteen are in the far west, one in the south, and one in the far east. Two are desert parks, three moderate altitude parks, and nine in the high mountains.

More specifically, three of these national parks, Grand Canyon, Zion and Glacier, illustrate the land forms produced by erosion

acting upon sedimentary rocks; four, Yellowstone, Mount Rainier, Crater Lake and Lassen Volcanic, show different phases of volcanism; three, Yosemite, Rocky Mountain and Lafayette, exhibit eroded granite; two, Sequoia and General Grant, preserve extraordinary forests; and one, Mesa Verde, preserves the most remarkable of our prehistoric ruins.

Again, seen in different classification, the parks illustrate the geologic sequence of America's making. From the Granite Gorge of the Grand Canyon to the top of the Pink Cliff in Bryce Canyon are displayed the colorful strata representing perhaps a hundred million years of world building, a library in brilliant bindings of the dramatic creation of our southwest. The volumes missing there may be found in Glacier.

Our granite parks illustrate the tremendous processes of the upbuilding of gigantic mountain systems, their destruction by erosion, and their rebuilding. The everlasting struggle between the uplifting forces from below and the wearing-down forces from above are illustrated in minutest detail. In Mount Rainier, we see full-bodied glaciers; in Yosemite and Glacier and Rocky Mountain we see the small remainders of once-mighty glaciers, and camp out in deep channels whose like are now making at Mount Rainier.

Our volcanic parks likewise tell their dramatic tales of tempestuous mountain building, of the blowing up and collapse of huge cones, of the creation of rolling plateaus, of hot springs and geysers as stages in dying volcanism. Lassen is a living volcano. Dead volcanoes are found in several parks.

Every national park makes its own different contribution to the great story, and in combination they tell us the whole minutely, dramatically, fascinatingly. Even the low granite knobs of Lafayette, emerging from inlets, add their chapter on the subsidence of the Atlantic Coast and the sea's invasion of valleys scooped by glaciers then fifteen thousand feet above the tide.

The processes which wrought America are seen in our parks in full operation to-day. Best of all, the popular lessons learned in these thrilling national museums have their application in every square mile elsewhere. The whole world becomes a new and eloquent and fascinating thing.

In all of them wild life conditions remain untouched. Except to make way for roads, trails, hotels and camps sufficient to permit the people to live there awhile and contemplate the unaltered works of nature, no tree, shrub or wild flower is cut, no stream or lake shore is disturbed, no bird or animal is destroyed. These parks are literally national museums of the original American wilderness.

In most of them wild animal life is restoring itself very slowly

from the generation of the great slaughter, when this land of most exuberant wild creature life was denuded in extravagant ruthlessness. But there are two parks, Yellowstone and Glacier, which were so remote then that they measurably escaped, and these to-day are fair examples, perhaps, of the animal population of the original wilderness; and another, Mount McKinley, in Alaska, which will preserve its immense herds of caribou and mountain sheep nearly intact, provided Congress is not niggardly in guardianship.

The educational value of our national parks is evident. If you question the opportunity, go to the parks and ask its visitors. Or stand on the rim of the Grand Canyon, or in one of the great forests of Yosemite, or on the shore of Iceberg Lake in Glacier—anywhere in any national park—and offer explanations aloud. Instantly you will become the center of an eager questioning crowd. With few exceptions those who visit our national parks want earnestly to know.

Wanting to know is one of the striking characteristics of the American people. The popular museums and school-rooms which constitute our national parks system, with their millions of waiting students, are not yet utilized. The system may be compared to a school equipped with every educational device, filled with eager pupils and with no teachers. I call the attention of this great scientific association to an incalculably valuable economic function of our national parks system almost wholly unused. The association which I represent was organized to promote the utilization of this opportunity among those professionally equipped to carry it through. That we have accomplished little toward this end is because, almost upon organization, we were called to the defense of the system's very existence against powerful attacks suddenly concentrated upon it. While we hold this opportunity safe, we invite you to avail yourselves of it.

Still another important economic function of our system of conserved parks may be illustrated by observing carefully the men and women who visit them. They include nearly every kind of American.

Every summer we meet a few of the distinguished and the conspicuous in the national parks. Politicians, merchants, legislators, artists, architects, bankers, judges, millionaires and the merely fashionable all are represented. But we meet in immense numbers business and professional men and their families, teachers, lawyers, brokers, manufacturers of everything on earth, writers, publishers, advertising men—the well-to-do of all sorts and degrees.

These constitute the great body of national park visitors. We

also meet the workers in lesser numbers—farmers, small employers and the thrifty employed.

Imagine an average of church congregations and the audiences of theaters, concerts, popular lectures, grand opera and the better motion pictures houses, of college football crowds and the patrons of the Chautauquas and Ocean Groves of the country, and you will come pretty close to the average of national park visitors. It is an intelligent and a fairly educated crowd. It represents America very well.

Of enormous economic importance is the system's strong tendency to redemocratize in a period which needs it. Nowhere else do people from all the states mingle in quite the same spirit as they do in their national parks. One sits at dinner, say, between a Missouri farmer and a Utah miner, and at supper between a New York artist and an Oregon shopkeeper. One stages it with people from Florida, Minnesota and Idaho, climbs mountains with a chance crowd from Vermont, Louisiana and Texas, and sits around the evening camp fire with a California grape grower, a locomotive engineer from Massachusetts, and a banker from Michigan.

Here, the social differences so insisted on at home just don't exist. Perhaps for the first time one realizes the common America—and loves it.

It is the democracy and the sense of common ownership in these parks that work this magic. They have rediscovered to America the American people. Elsewhere travelers divide among resorts and hotels according to their ability to pay, and maintain their home attitudes. In the national parks all are just Americans. It is difficult to imagine an institution making more powerfully for national solidarity than this annual congregation of a million and a quarter Americans from all the states.

We need not dwell upon the purely recreational values of the national parks, because they are self-evident. No other wilderness areas in the world are equipped, acre for acre, as these are with hotels and camps and public camping grounds, with roads and trails, for the pleasuring of the people. Though recreation is the national parks system's secondary purpose, shared with many other wilderness reservations, national and state, it here reaches its highest expression.

But we are nearing a danger limit. So rapid is the increase of travel to the parks that it is none too early to anticipate the time when their popularity shall threaten their primary purpose. This amazing era of travel is in its mere infancy. Motor touring and wayside camping are destined to increase many fold. If for no other reason than to protect the purpose of our national parks sys-

tem, we may do well to consider the large development of the admirable recreational areas in the national forest and perhaps the creation of a system or systems of purely recreational reservations elsewhere in the public lands. There must be new outlets or our conserved park system will suffer. While we are fighting for the protection of the national parks system from its enemies, we may also have to protect it from its friends.

The limits of this paper prevent even the enumeration of other economic aspects of our national parks, of which there are many. Those I have emphasized are in my opinion their greatest. The discussion of their value to adjoining states as concrete income-makers itself would need a paper. Their value to railroads and local business as nationwide travel-makers can never be computed; they are the headliners in railroad advertising and motor touring prospectuses the country over. Their income-producing value as lures for foreign travel here is destined to become very great; steamship lines and international travel agencies already are preparing for its coming. In fact, its beginning is here.

Time permits no further catalogue, but to this audience I must at least mention the fact that they are much the largest, and in two instances, at least, Yellowstone and Mount McKinley, the most important of our wild animal reservations. The last of the Shiras elk and of the unherded buffalo live in their ancestral corner of Yellowstone rarely even spied upon by man. One of the last small bands of the swiftest and most graceful of American wild animals, the prong-horn antelope, doomed, alas, to quick extinction, ranges her opens. McKinley's vast herds of caribou, and the innumerable big horn sheep upon her cliffs have been protected just in time.

I close with a suggestion which deserves thoughtful consideration. The reorganization of the administrative departments of the government which the President will urge upon the next Congress contemplates the creation of a Department of Education and Public Welfare; and in this new department the national parks service undoubtedly would find a more sympathetic and effective background and administration than grouped with the scientific and engineering bureaus which it is purposed to concentrate in the Department of the Interior. The engineering work in the national parks, confined to the building of roads and trails, is merely incidental to general and specific purposes which, even now, find little in common with the bureau's present environment. Our national park service is in its best and fullest sense a service in the interest of education and public welfare, nothing less and nothing else.

The American Association for the Advancement of Science has already importantly influenced national park policy by protest

against the importation of foreign species. We hope for its future hearty cooperation in many ways in order that this nation may realize in full measure the benefit of our national policy of complete conservation.

CONSERVATION OF THE QUALITY OF THE RURAL POPULATION

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IN these days of reconstruction there has come to the front again the old question of the relation between population and food supply. Even if we are not convinced by the arguments intended to prove that the world is approaching the point of population saturation, we can not fail to recognize that the effort to provide for an increasing population must soon involve either greater food production or a further lowering of the standard of living.

We can not go far in considering this question without discussing the relation of the farmer to the probability of an overcrowded world. We already have our alarmists who think that the drift from country to city, even in America, has come to be very serious. They regard this drift as the prime question in conservation, and they want something done to stop the flow from the farm. Of course the immediate answer to these worried souls is that with the use of farm machinery and the improvement of farm methods fewer farm workers are needed to feed the rest of us, and that the adjustment between food producers and food consumers will work itself out on sound economic lines.

Nevertheless, the problem of possible overcrowding is not entirely settled by this prompt reply. We know that the question of possible overcrowding is not spatial—there is standing room for billions more. Nor is it much a matter of shelter or clothing, because for centuries to come wood and iron and steel and clay and the fibers are likely to suffice for world needs. But when we come to food we do need to have concern. The amount of good soil was always limited, and the human race thus far has been inclined to waste even this patrimony of soil fertility. Now while the question of food depends upon the farmer it does not depend primarily upon the number of farmers. There are other factors, such as the maintenance of soil resources and the rehabilitation of those already partially wasted—no man knows the extent to which this rehabilitation can take place, as indeed no man knows the extent

to which unused tracts can be made sources of supply; the skill of the farmers; their ability to increase production per unit of land while maintaining fertility and at the same time keeping up their own standard of living; the economical distribution of food, the great problem of the next two decades; the changes in dietary of the consumers. On this last point, for example, there can hardly be any doubt that population pressure will gradually force people to emphasize the vegetable rather than the meat diet.

The man who holds the situation in his hands is the farmer. Two thirds to three fourths of the world's population consists of farmers and their families. The world's food supply is dependent upon these people. The conservation of what is by far the greatest natural resource of this earth, soil fertility, is wholly in their hands. They furnish a major part of the raw material for manufactures and commerce. They are potentially the largest consumers of urban wares. If intelligent, they forward the democratic movement; if ignorant, they retard it.

But this is not all. Shall we ever practice the precept which we know to be true that life is more than meat, that the economic fabric is only a scaffolding on which to work in the erection of quality of human life? As a matter of fact our fundamental question is not maintaining economic power nor political strength nor even intelligence, except as those things are both the result of and are used to develop qualities of mind and spirit. It has been shown to be quite possible to secure a national agriculture which is economically efficient, where at least the return per acre is very high even though the return per worker may not be large; and that men of the soil under such a regime may possess great thrift, may be contented and happy, and may through cooperation even develop considerable group power. I am describing here a thoroughly peasant regime. But in America at least we have to be persuaded that this status is satisfactory.

So much for a broad statement of the problem of maintaining the quality of our rural folk. Now to the solution. Of course the problem of conservation of the rural people is not in essence widely different from the problem of conservation of urban people. But the conditions of rural life differ widely from the conditions of city life, so widely that rural psychology is not urban psychology. Rural institutions can not be handled in the same fashion as urban institutions. So we get the rural problem, which, in all its practical aspects, is different from the city problem.

The prime need for the immediate future among our rural people is the conservation of intelligence. The whole farm stock in America has never been excelled and probably never equalled. At

the start it was essentially the same stock that dwelt in the towns and cities. Indeed, for a period of two generations in the nineteenth century our cities were built out of our own farm people. This high quality of rural folk in America is exceptional. There have been places and periods in the history of the world, such as in the earlier days of the Roman Republic and of the heyday of the English yeomanry, when the farm people could hold their own in the existing civilization. But as a rule the farmers have been underlings; so much so that the very words "boor," "rustic," "heathen," "pagan," and even "clown" and "villain" find their roots in the soil. The basic distinction of our American farmers, as contrasted with these other groups, is in the degree of intelligence. We can not here debate the question whether the intelligence of the American farmer is or is not being maintained. We can say, however, that there is the most serious danger that it may not be maintained, and this in spite of the great influx of "ignorant" immigrants to our cities.

Following closely upon the heels of this phase of conservation is the question of the health of the rural people. The last two decades have wrought great changes in the field of public health as it relates to "urban versus rural." The difficulties of distributing health information, of enforcing health regulations, of providing public health facilities are much greater in the country than in the city, and in some regions of the country these difficulties override the natural health resources of the country in the form of pure air and fresh food and abundant physical exercise.

Economic efficiency is a third item to be considered. On the side of production, I think the American farmer has held his own on the whole with other classes. It is popular to call attention to the tendency of the farmer to do as his grandfather did, to fail to keep accounts, to leave his tools in the field, but it is very questionable whether all the wastes in agriculture aggregate any larger relative item than the wastes of manufacturing, when we consider losses from misplaced capital, the scrapping of machinery, and the restriction of labor output, not to mention poor management, labor troubles, and the rest. To say all this, however, is not to deny the chance for vast improvement in the efficiency of producing plant and animal food. The ideal, of course, is that every acre of tillable land shall produce its maximum, but still retain at least its original fertility unabated and if possible increased.

This slogan, however, immediately opens the door to the entrance of another factor in the economic efficiency of American agriculture, and that is the problem of distribution. We are now in the throes of a great effort to solve that problem. To use a popular

phrase, the difference between the consumer's dollar and the producer's dollar must be decreased. The "spread" is too wide. Here is a vast complicated field of reform. There is but one country in the world that seems to have worked it out successfully, and that is Denmark, with a small territory, a simple agriculture, and remarkable unanimity of sentiment, acting under terrific pressure of outside circumstances. If, during the next generation, the American farmers even approximate the success of Denmark, we will be fortunate.

Of course, the great all-inclusive problem of conservation is that of conserving social power. Doubtless in an industrial age the main item in social status is economic efficiency and power; that we have already discussed. But it is not the sole term. There are other considerations. The joy in work, the appreciation of environment, the attitude toward other classes, the ideas and the ideals of the rural people, yea, their religion, are after all the great human items in a conservation program. In other words, American rural civilization must be just as broad, just as deep, just as humane, as any other part of our civilization. Not only that, but it must also make its contribution to our total civilization. It must play its part in great affairs. Social power, in other words, does not consist alone in successfully maintaining group strength and group rights. It consists also in an instinct for asserting itself in every field of social reform and endeavor. For example, the working out of satisfactory international relations does not lie wholly with the diplomats, nor with the statesmen, nor with the traders, nor with the bankers, nor with the prophets, but some of it resides with the farmers at work on the soil.

Now a word about the main forces to be relied upon to secure conservation. As I see it, there are two, both old-fashioned, but fundamental. One is education, the other is organization. We have rural schools in every community, we have the most elaborate system of agricultural education in the world, but we have yet a long way to go before we have an adequate system of rural education. In general the rural schools are not keeping up with the city schools. And, splendid as is the work of our extension education in agriculture, it has not yet begun to develop in a systematic fashion either the agencies or the methods necessary to meet the situation. In this presence, I do not need to dwell on this problem of education.

The stock arguments for organizing group endeavor do not as a rule include the educative value of organization, that is, the human improvement aspect of it. This is natural because the first endeavor of associated effort on the part of a group is to retain old rights or to secure new ones. The association arises because

these rights are endangered or have passed, and so there ensues a group warfare, and interest in the militant aspect of the problem comes to the front. As a matter of fact, however, the development of individuals within the group and the inclusive social power of the group itself are tremendously advantaged by associated or collective effort. This is quite as true of farmers as of labor or any other group. I should not look for any adequate solution of this problem of conserving rural people unless they can become thoroughly organized for all economic and social purposes. . . .

There is no opportunity in this paper to discuss a constructive program. A list of apparently dogmatic assertions may, however, be made covering the more significant points in a well-considered working program of rural conservation.

(1) The country children and youth should have opportunities for education fully equivalent to those offered the city-dwelling children and youth. This is not now the case.

(2) Our system of rural schools should provide education for those who wish to leave the farm as well as for those who stay; should stress vocational training for farming and rural home-making; should appreciably enlarge facilities for high school education.

(3) Financial aid to rural schools from the federal government will probably do more than any other one measure to stimulate this efficiency and broaden the scope of rural education.

(4) The American system of agricultural extension is the most stupendous scheme of adult education in the world. But we have yet to develop a satisfactory plan of permanent rural community forums or discussion centers as well as a system of study clubs and reading groups.

(5) Organization is a principle that goes far beyond mere collective or group efforts, important as those are. The main needs of the immediate future are (1) the organization of real local rural communities, each with its own program; (2) state, regional and national programs which not only project the larger issues but which actually secure the cooperating allegiance of all the agencies and institutions that can help. (3) A realignment of existing agencies in terms of their functional efficiency in these local and wider programs, rather than in terms of institutional pride, power or mechanism.

(6) A "campaign" of public information among the urban groups, to the end that they may come to a fuller appreciation of their interdependence with farmers, and the significance and difficulties that lie in the rural problem, especially in its economic and social aspects.

(7) Education and organization should seek not alone the special group interests of farmers, but should quite as consciously endeavor to mobilize rural opinion and activities on behalf of the common needs of humanity.

(8) We should have a Rural Foundation, well endowed, free to study and to interpret without bias the fundamental issues involved in the effort to conserve the quality of the rural population in all parts of the world.

I have used the word "quality" as indicating in a large way those powers and characteristics that spell effectiveness and social capacity. There are, however, certain specific qualities, certain habits of mind among rural folk, that are well worth possessing. Their thrift, their simplicity and directness of thinking and acting—these and other qualities do seem to be engendered by the rural environment, and more than once they have been a bulwark of our civilization. Of course we have to admit that rural environment may also develop other qualities not so pleasing. Nevertheless, on the whole the qualities engendered by the rural mode of life are substantial, worth while, significant.

The wise man of Ecclesiasticus long years ago asked this pointed question, "How shall he become wise that holdeth the plow, that glorieth in the shaft of the goad, that driveth oxen, and that is occupied in their labors, and whose discourse is of the stock of bulls? He will set his heart upon turning his furrows and his wakefulness is to give his heifers their fodder." And in this wise man's opinion, so also is every artificer and workman, the smith sitting by the anvil, and the potter sitting at his wheel. "All these put their trust in their hands and each becometh wise in his own work." They have the fundamental task of maintaining "the fabric of the world." But there follows this significant addendum, "They shall not be sought for in the council of the people and in the assembly they shall not mount on high; they shall not sit on the seat of the judge; and they shall not understand the covenant of judgment; neither shall they declare instruction and judgment." This ancient social distinction between those who work with their hands and those who do not still maintains in practice in most countries. In America we have rather prided ourselves that the line could not be so sharply drawn, and we have worked for and found wisdom among the husbandmen and the artificers.

In our thinking about how to conserve the quality of the rural population, therefore, we may take our departure from either one of two points of view. We may take for granted that the great task of the tiller of the soil is to be supremely efficient in that

function and that alone; or we may treasure the hope that in the evolution of human institutions the rural group, with respect to intelligence and education and social capacity generally, shall quite hold its own with other groups.

THE CONSERVATION OF HEALTH

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Introduction

TO present a comprehensive picture of what is implied by the extremely common term "conservation of health" is a difficult matter. When this topic is under consideration we are not dealing with something to be weighed by the ton, measured in board feet or calculated in kilowatts but with a subject whose inherent qualities defy exact measurement or even precision of definition. It is a subject concerning which, curiously, almost every one has some rather definite convictions, but one in which the formulæ of one group may be entirely rejected by another group. As soon as the value of a scientific fact in preventing disease or increasing vitality has been adequately demonstrated, one type of human mind concludes that this fact or discovery ought to be forthwith applied to the entire population willy-nilly. But there also exists another type of mind that tends to consider all health work as partaking in varying degrees of the faddish in quality and to look with skepticism upon all alleged advances in health conservation. This attitude seems to be due partly to the fact that the results in life saving or kilograms of additional physical energy can not be accurately calculated and partly because this type of mind cherishes strongly the principle of the right of the individual to do just whatever he chooses.

Between the two extreme views, that of the impractical enthusiast on the one hand and of the sanitary cynic on the other, must lie the real solid field of accomplishment in health conservation. There is, I feel, an actual danger from unbridled enthusiasm in health conservation proposals. It is conceivable that human life might become so completely safeguarded against accident, infection, fatigue, systemic toxemias and mental and nervous strain that existence itself would become so monotonous and boring as to be almost not worth while to a large proportion of individuals. On the other hand, the carrying out of the doctrine of individual "self determination" to the extent of refusing to admit the truths of science or of refusing to admit the existence of any obligations

on the part of government to citizens, parents to child, employer to employee, or individual to the community, in health matters, is a terrible thing to contemplate. Yet there are elements in our national life, some active, noisy, self-seeking, others earnest and fanatically sincere, who unite in propaganda whose objective is nothing less than the destruction of all governmental or private efforts for the conservation of health.

Health conservation has one underlying peculiarity which is shared by but a few of the other subjects concerning which conservation is a live issue. The conservation of health can never be completely achieved in its broadest sense by statute or by the expenditure of money alone, important as both these considerations are in any sane national health conservation program. The conservation of health depends in the last analysis upon the conscious desire and conscious voluntary response to that desire of animate, free agent, human units acting sometimes collectively, sometimes as individuals.

Part I. Health Conservation of the Past

It has been aptly said that the only guide we really have in planning for or in predicting the accomplishments of the future is the experience of the past. Only by tracing back to its beginning can the present structure of health practice be properly evaluated, present problems seen in perspective, or future trends even tentatively predicted.

It is noteworthy that this whole subject is of remarkably recent origin. There is some temptation to go into the splendid achievements of antiquity in certain lines of health promotion as exemplified by the systems of the Roman baths or Grecian athletics, for instance, and deduce from these isolated instances that there was a sound intelligent system of health preservation operating in classical days which was lost to the world for a long time thereafter. But save in the important sense in which security of property and safety of life tend to encourage higher standards of comfort and nutrition there is little to justify the assumption of the existence of a clearly comprehended general program of health conservation during the classical period. This statement does not mean that there did not exist a deep interest in health or in various carefully elaborated systems of dietary, exercise, baths, etc., designed to promote individual health, but community health measures were most rudimentary and totally ineffective in periods of epidemic or disaster, and superstition or irrational and nonsensical theories were more apt to determine lines of hygienic procedure than scientific knowledge or even common sense.

Down to relatively recent days two prevailing theories fought for control of communal and personal health policies. The one that gradually predominated and settled for centuries like an incubus over all attempts at advance was the theory or belief that all illnesses, pestilences and deformities were a direct manifestation of Divine wrath and hence that it was nothing short of impiety to make any attempt towards their control. This theistic point of view reached its climax in the latter middle ages and is perhaps no where more graphically expressed than in the words of an orthodox physician of the city of Reggio, Italy, when the reigning dukes (brothers and apparently men in advance of their times) during a plague epidemic introduced the revolutionary procedure of forced isolation of the sick from the remainder of the people, with the further drastic provision that if any parish priest or civic authorities failed to report cases coming to their attention at once they would suffer the death penalty. All this occurred in the year of our Lord 1374 and the comment of the orthodox physician of that day is as follows, "And I saw in this same year that these orders were observed in Reggio for which cause all were more grieved and terrified than by the fear of the pestilences, which, when God permits it, can not be arrested."

The type of mind which sought for rational and natural causes as an explanation of pestilences and epidemics was always hopelessly handicapped by the lack of any concept of the nature of microscopic life. Hence for centuries the scientific world elaborated and discussed theories of "miasmas," "atmospheric corruption" and the like which make pathetic reading to-day in their blind gropings for a natural explanation of the destructive whirlwinds of epidemic disease which periodically devastated the ancient and medieval worlds.

Apart from their inevitable limitations in the fields of epidemiology and sanitation the ancient physicians, who were often also priests of various shrines, evolved systems of personal hygiene and courses of treatment at various famous health resorts which were based on sound commonsense principles and produced results.

Where Modern Health Effort and Preventive Medicine Begin

Modern preventive medicine or hygiene may really be said to date from the discoveries of Pasteur in the world of bacteriology. The beginning of modern conceptions and practice in the field of sanitation in general and in sewage disposal and water supply and housing improvement in particular antedated the era of Pasteur by over a generation and to them modern health practice is under a great and everlasting obligation. It is not illogical to call the

earlier phase of present-day health practice development the era of sanitation or sanitary engineering. The epoch-making discoveries of the pioneers in bacteriology naturally took some time to reach even the leaders of medicine and general science. In fact, it was not until the late 80's of the last century that the leaders of clinical medicine in either Europe or America can be said to have generally accepted, with all the revolutionary implications contained therein, the demonstration of the existence and practical significance in health or disease of the bacteriologic world. The principles of modern sanitary engineering were already being steadily applied with notably beneficial results in matters of housing and community sanitation, but the demonstration concerning the micro-organic world was soon put to practical utilization in water and sewage filtration by sanitary chemists and engineers. One great plague, typhus fever, was placed under control during the earliest stages of modern sanitation. It might almost be said that, like Hercules, the infant science of sanitary engineering throttled this monster in its cradle before it was old enough to comprehend the significance of its efforts.

Without attempting to follow chronological sequence or to place any emphasis as to their relative weight as factors in our present day body of public health practice several elements entering into the modern health movement deserve passing reference. All have played a definite part in our achievements in these directions. Some of them are exclusively concerned with health conservation; others have come into play as a result of economic or social advance and their great health significance has often been entirely overlooked even by lifelong students of sanitary science.

The Factor of More Widespread Education

Foremost among these is the growth of modern education. It is sharply questioned to-day by some whether our modern system of universal literacy and diffusion of information really constitutes education. One brilliant student of human affairs in an article recently contributed to a leading American magazine frankly takes the ground that we have made no real advance over Hellenic civilization in true education. Be that as it may, I firmly believe that modern public health achievements would have been utterly impossible save by imparting a rudimentary understanding of modern sanitary science to the masses in school and by our books, papers and magazines. Lacking an at least partially-informed public opinion in these matters, progress in modern health endeavor would have been far below its present mark. The remnants of ancient and medieval pseudo-science transmuted into the superstitions, folk lore and "old wives' tales" of modern times still remain one

of our greatest obstacles to the more universal acceptance and application of the life-saving principles of hygiene. If the influence of our modern school systems and the dissemination of knowledge generally by books and periodicals were not partially neutralizing the subtle mischief of these inheritances of barbarism and superstition, the passive resistance offered thereby to the progress of hygiene would be almost insuperable.

Relation of Insect World to Disease

A prominent place among the factors of modern health development must be reserved for the far-reaching discoveries of the relationship of the insect world to disease. The knowledge of the relationship of the mosquito to malaria and yellow fever, and of the flea to bubonic plague, to cite outstanding examples only, has been of great significance to all of us, and not only has this knowledge resulted directly in great saving of human life, but indirectly it has meant much already and in the future can not help but mean vastly more in greater freedom of intercourse and trade among nations and in the opening up of vast areas of the world's surface to agricultural or other uses.

Extension of Food Resources

A matter usually ignored in consideration of the factors of health conservation is the matter of food supply. I am not now considering the problem of personal nutrition or proper balance of metabolism. The thought it is desired to bring out here is the hygienic importance of having enough food of sufficient variety produced and distributed at a cost which the masses can meet. Here is the true cause of much of the happy results of modern life saving for which we are altogether too prone to give credit exclusively to the laboratory and microscope, the surgeon's knife and the physician's pill. Among the many startling object lessons of the great war none has been more dramatic than the revelation of what a period of widespread inadequate nutrition means in the morbidity and mortality tables of a nation or community. In looking back we see plainly that it was the recurring famines, followed always by fearful pestilences, which largely account for the almost incredible mortality rates of the middle ages.

Modern health work is under tremendous debt of obligation to those discoveries in soil chemistry, to both animal and plant breeding and to the invention of modern agricultural machinery, which together have resulted in the present standards of quantity and cost in the matter of food production.

Factor of Improved Transportation

Bountiful production of food at reasonable cost is not by any means the whole tale of the fundamental bearings of the subject

of food upon health. Transportation and preservation of food by various devices have played a large part in making possible the all-year-round supply of a dietary adequate for the maintenance of the metabolism of the masses on a basis never before remotely approached. Rapid transit, modern canning processes, cold storage have all contributed to this phase of advance in health conservation.

Improved Standards of Living

Another factor which has entered largely into the evolution of better health standards has been what is commonly comprehended by the phrase "standard of living." This is an expression which does not lend itself well to exact definition. It implies matters of esthetics as well as matters of sanitation, but in such details as increased facilities for recreation and exercise, better-ventilated, heated and lighted houses, workshops and buildings devoted to commercial, educational and amusement purposes, it has contributed much to the conservation of our health.

One phase of the "improved standards of living" phenomena deserves, though it all too seldom receives, special recognition for the part it has played in health promotion, and that is the development of the science of plumbing. Nothing more clearly illustrates the advance in health conservation of the past century in this country than the great advance in the amount of water per capita that is used by the average person or family to-day when contrasted with the corresponding water consumption of a few decades ago.

Effect of Improved Hours and Conditions of Labor

A factor in the gains of our era in health promotion and life prolongation that can not be ignored is the economic or more often the combined economic and sociologic factor. A leading American public health authority[1] concludes a recent critical study of the causes of our present striking decline in tuberculosis deaths with the statement that the improved earning capacity and shorter hours of labor of the average American wage earner have contributed more to this decline than all the institutional and medical care and general educational aspects of the anti-tuberculosis movement combined. Perhaps not all will be willing to go so far as this, but that such a statement can be made by a qualified expert in the field of preventive medicine and be generally accepted in medical and sanitary circles as a substantially sound scientific judgment is the best possible evidence of the degree to which modern sanitarians

[1] Emerson, Haven: "The Factor of the Declining Death Rate for Tuberculosis." *American Journal of Tuberculosis.*

look to the field of economics and sociology for furtherance of their objectives.

Both the amount of compensation of the worker and his hours of toil are of deep significance in determining the general health of the community. It is also true that specific safeguards against the hazards of industry are a prominent part of any health conservation program. From industrial stress and strain, from extremes of temperature in industry, from dust, smoke and fumes, from undue general or local fatigue come much physical impairment, shortness of life, industrial inefficiency and community impairment. The rapid growth of the science of industrial hygiene has been the answer of industry to the significance of these discoveries.

Hours of and Character of Labor for Women and Children

Growing appreciation of the significance of woman as the replenisher and of the child as the hope of the race has wisely led to safeguards such as the world has never before witnessed against the exploitation of the mothers or the children of the nation by industry. It is too early yet to determine the full effect of these still only partially-realized national policies, but that their contribution towards greater national vitality will be a substantial and important one is beyond question.

The Contribution of Medical and Laboratory Science

Having considered a few of the most important underlying contributions to health advancement it is now appropriate to weigh the significance of those factors usually thought of when the terms "health work" or "preventive medicine" are used. Reference is meant to the direct bearings of research in pathology, bacteriology, physiological chemistry, entomology and their newer subdivisions, together with the contributions of clinical medicine and epidemiology proper upon the cause of health conservation as weighed and evaluated by the methods of vital statistics. This is what is commonly meant when the term "public health" is used. The successes of modern science against such immemorial enemies of human life as Asiatic cholera, hookworm, smallpox, diphtheria, scarlet fever and a long roll of less well-known diseases can be traced back almost exclusively to bacteriological laboratory discoveries supplemented by careful clinical observation and as a result of careful study and correct conclusions as to their significance, the application of practical methods of prevention. In the case of such maladies as yellow fever, typhoid fever, malaria, bubonic plague and typhus fever, the same bacteriological-medical factors have been prominent, but the sciences of entomology or engineering have had to play an equally important rôle before success could be achieved.

In the case of another disease group of great destructiveness to human life and efficiency, the so-called "venereal" infections, in addition to the discoveries of the laboratory and hospital, ethical considerations must be depended upon for any great or permanent advance.

THE PHENOMENON OF HEALTH DEPARTMENTS AND OTHER ORGANIZATIONS

Step by step with these discoveries has grown up during the past fifty years a remarkable number of agencies designed to function exclusively for the preservation of human health. Some of these are agencies of government operating under different names and given very widely differing prominence all the way from the health department whose whole aim, object and reason for being represents the reaction of modern organized society to the challenge of health conservation, down to very minor organizations in governmental departments whose primary purpose is remote from health, but whose everyday functioning uncovers specialized health problems for the handling of which it has been found necessary or advisable to create special health machinery.

Side by side with these health departments have also gradually come into existence a vast host of non-governmental agencies whose objective is the promotion of health. These range all the way from the vast endowed organizations, as the International Health Board of the Rockefeller Foundation, for instance, with a budget and resources far in advance of practically all governmental health departments down to the smallest village's band of public-spirited women who have united to ensure the services of a home visiting nurse for the community. In the promotion of health the influence of these organizations in the aggregate has been tremendous.

STATISTICAL RECORD

Now let us see very briefly what the record of fact shows in the gains of health conservation up to the present. After all, the crucial test for health conservation to meet is not so much what may be its province in the future, but what it can show in the matter of past performance. Happily for students and practitioners of sanitary science in this respect we are on much firmer ground than the special pleaders for many other forms of conservation. To present an elaborate statistical analysis as a basis for this statement, interesting though it might be, would unreasonably prolong this paper, hence I will merely cite a few salient features of Massachusetts' experience, with the general qualification that they may be accepted as typical of all localities where the occidental type of civilization prevails.

In Massachusetts the average yearly death rate from all causes from 1885-88, inclusive, was 19.5 per 1,000 population; for 1920, the rate was 13.9 per 1,000. This means over 20,000 more lives were prolonged in comparison with the rate of about thirty years ago.

The infant mortality rate of Massachusetts in 1885 was 156; for 1921 it was 76. It means that whereas in 1885 a new-born infant had only a little better than five chances in six of living to celebrate a first birthday, now less than one child in ten dies under the first year—a most creditable gain but still a fatality hazard much higher than we know to be necessary.

The death rate for pulmonary tuberculosis in 1885 was 307 per 100,000; in 1920 it was 96 per 100,000. It means that if the tuberculosis death rate had remained to-day what it was in 1885 in place of approximately 3,300 dying this year from consumption the number would have been over 12,000.

In 1885 the typhoid death rate of the commonwealth was 39 per 100,000; in 1920 it was 2.5. This means that, whereas less than 100 people died from typhoid in 1920, had the same rate prevailed as in 1885, 1,560 would have died.

In 1885 the death rate for diphtheria in Massachusetts was 78 per 100,000 of population, in 1920, 15 per 100,000 population.

In 1885 the death rate of scarlet fever per 100,000 population was 30.2. In 1920 it was 5.5 per 100,000 population.

Or it is perhaps more graphic and comprehensible to reduce the matter to terms of average expectancy of life at birth.

In 1885 the average expectancy of life for a new born baby (male) in Massachusetts was 42 years approximately; (female) 43.5. Both sexes average 42.75 years. In 1920 the average expectancy was 53.98 (male), 56.33 (female); both sexes, 55.1 years.

Upon reflection we can see that up to a period roughly coincident with the end of the first decade of the present century all the influences operating most prominently in connection with health conservation have certain features or characteristics which mark them off to a certain extent from the health conservation of problems of the present and near future. In general it may be said that hitherto the greatest emphasis has been placed and the greatest advances made in the field of infectious disease prevention and control. It is also quite obvious that except in the case of the infectious diseases such gains as have been made in promoting the health of the individual or the mass have often been due to the accidental or unexpected results of some improvement in industry, transportation, recreation or sociologic endeavor rather than to a conscious deliberate attempt thereby to improve the health of the individual or community. It may also be said with a high degree

of accuracy that the health advances of the recent past have generally represented those things that could be done for the average citizen rather than those things which he had to do for himself.

As we turn to consider the future problems of health conservation we will note that all three of these factors will cease to be as proportionately effective as heretofore and must be replaced by procedures along radically different lines if the full potential benefits of a sound national health program are ever to be realized.

Part II. Health Conservation of the Present and Future

I have traced roughly some of the sources from whence our present health-conserving agencies have sprung and have drawn attention to the crude proof of their accomplishments as registered in increased average longevity and decreased fatality from specific morbid processes.

Broadly speaking, no such results have ever been remotely approximated before in the world's history—Egypt, Hellas, Rome, India or China knew nothing like it in the days of their greatest glory. This record of achievement is one thing which sets our era on a pinnacle apart from the remainder of recorded human existence. To be sure, deep concern over the human misery arising from bodily affliction has long been a great moral force in the world but it is only in our own times that humanity's struggling aspirations for the alleviation of suffering have been translated into scientific achievement.

An outstanding feature of present-day health aims is the degree to which they recognize how far the lengthening of average expectancy of life up to the present time falls short of the full possibilities to be attained as an outcome of a comprehensive well-rounded national health program. Past accomplishments in health improvement have consisted largely in triumphs over environment and in control of infections. It is in hookworm and malaria eradication, in diphtheria control; in the tuberculosis decrease that we read most clearly our claims to distinction. In building up the well-poised body and in cultivating the serene mind we can point to no such clear-cut victories. In these respects some authorities do not consider that we can even equal the actual accomplishments in personal hygiene that were achieved by the citizens of ancient Greece.

It should never be forgotten, however, in making such comparisons that the free citizenry of ancient Greece never represented more than ten per cent. of the total population. No records have come down to us relative to the hygienic conditions or mortality rates of the slaves and serfs who represented ninety per cent. of the populations of antiquity. When proper allowance is made

for the status of the slave in classical times, I am reasonably certain that our average achievement in personal hygiene to-day far surpasses the average standards of antiquity.

But to revert, it is an inescapable fact that most of our gains in life prolongation hitherto have been in channels where either correction of faulty environmental conditions or an interruption of the chain of infection was indicated. It is a peculiarity of these two types of health activity that they can be carried out to a large degree by the mere passive acquiescence of the bulk of the community. It is obvious that even where efforts and results in these directions reach the maximum there will still remain untouched large segments of the health conservation field.

The Expanding Concept of Health

These newer and as yet untouched or only lightly touched phases of health development call increasingly for active participation by the individual citizen, and this question of the reaction between the offerings of science and their acceptance by the average American citizen in the field of health promotion presents one of the most fascinating problems of our present day schemes of human government and social relations.

There has sprung up in the past twenty years a greatly expanded concept of what health actually means. Now we are beginning to realize that but a small proportion of ostensibly well people can measure up to even very modest standards of good personal physique; that scarcely any of us out of a hundred pursue a reasonably sensible routine of personal hygiene.

To-day we are no longer satisfied with a mere negative definition of health. Health must mean something more than mere absence of acute disease. It implies a standard of personal vitality and physique that insures a positive enjoyment of existence due to a properly balanced, well-exercised, smoothly functioning bodily mechanism reacting agreeably upon the mental and emotional processes of the individual.

One of the outstanding difficult problems of preventive medicine is that of bringing home the extent to which avoidable sickness, inadequate or improper physical training in childhood and preventable accidents all considered together, slow down our national productiveness; absorb time, money and energy that could otherwise be devoted to the greater expansion of a national cultural life; result in increased delinquency and crime; and in general add to the sum total of preventable human misery. I will not go into exact statistics on this point. The publications of the National Safety Council present a mass of startling information as to the

burden of preventable accidents; the publications in recent years of the various social welfare organizations and of departments of correction, probation and charities of certain states and cities show how direct and extensive is the relationship between delinquency and non-social behavior on one side and physical deficiency or subnormal health on the other. We have begun to accumulate a certain amount of data on the magnitude of the burden imposed on society from occasional illness, a large proportion of which could be entirely avoided through sound intelligently applied systems of community, industrial, school and personal hygiene.

Inasmuch as such data on this subject as is available in this country is fragmentary and not checked by any nationwide machinery it may be more illuminating to quote the most recent British experience on this point.[2] This quotation is made without reference to the ability of the British system of state-supervised medical practice to correct effectively the condition disclosed. The impressive facts as to sickness prevalence are sufficiently startling in themselves without here going into any consideration of the proper answer to the national problem they so clearly indicate. The British health insurance tables show that "at least 14,476,000 weeks' work are lost on an average every year through sickness. . . . That is to say, in England and Wales there is lost to the nation every year, among the insured population only . . . the equivalent of the work of 278,000 persons (working constantly throughout the year) . . . it is not only the working equivalent of 278,000 persons that the nation loses every year, but also the labor and expense involved in their care during the 14,476,000 weeks of their incapacitation. To this loss of time and capacity among the fourteen million insured persons, we must, to obtain the (total) national loss, add a comparable (and undeterminable) though presumably not so large proportionate loss, in respect to the remaining twenty-three millions of persons, including children." So much for the facts of sickness prevalence.

The next finding of the British health insurance scheme is the one which opens up a wide range of discussion as to the reasonableness of this enormous aggregate amount of recorded sickness. It is reported that when the causes of sickness which result in this staggering amount of national non-productiveness are sought the absences from labor due to serious diseases such as organic heart disease or tuberculosis, for example, are relatively few, but it is what is generally known as the minor maladies, such as functional impairment of digestion or of kidneys, neuritis, neuralgia,

[2] Sir Geo. Newman: For year 1921, p. 27, Annual Report, Ch. Med. Off. British Ministry of Health.

sick headache, decayed teeth, tonsilitis, bronchitis and common colds, "rheumatism," etc., that are the principal causes for which these persons seek medical advice and absent themselves from work. In the aggregate these "minor ailments" produce a truly formidable amount of suffering, sickness, idleness and loss of income. An exceptionally large proportion of just such ailments are entirely avoidable by attention to personal hygiene. Hence we see that the preventive medicine of the future must seriously concern itself with this problem as well as with its present recognized duties in sanitation and communicable disease control. The question of how this problem is best solved, whether by an enormous extension of governmental activity into the realm of the private citizen's personal concern or by a great and revolutionary change in the conception of clinical medicine, is totally a different problem and not within the scope of this paper.

The Newer Terminology of Health

This swing of the pendulum away from consideration of mass groups of the population and towards emphasis upon the health problems of the individual is now very noticeable in all lines of health work and is the best evidence now available of the direction in which we may confidently prophesy that the future developments in health work will lead us. The very nomenclature coming into common use to designate the major divisions of health activity with the word "hygiene" occurring practically uniformly as the part of the name, as school hygiene, infant hygiene, dental hygiene, mental hygiene, for example, contrast sharply with the older divisions with which we have long been familiar—sanitary engineering, epidemiology, vital statistics—words indicating mass or group conceptions as sharply as the newer terms indicate the individual.

Enumeration of Prominent Health Fields of the Future

It will perhaps suffice, in view of the necessary limitations of the present occasion, to indicate some of the hygienic measures which I can already see coming into prominence in health conservation and which must inevitably come into much greater prominence in the future.

Eugenics

First of all comes the field of eugenics. Eugenics has become something of a football word, kicked about and mistreated by all sorts of special groups. That positive eugenic principles will ever become a significant feature of either national or personal hygienic practice has long seemed to me the height of the improbable. Despite the solemn pronouncements of a small group of enthusiasts

who preach the physical salvation of this world by the eugenic route, human nature has never shown any tendency to be guided by eugenic considerations in approaching the question of mate selection, and I see no reason to conclude that it ever will. On the other hand, negative eugenic principles deserve to be much better understood and it is reasonable to suppose that an important phase of future health development will be the education of individuals to a point where the dangers of perpetuating and multiplying racial defects by unwise mating will be so generally recognized that such traits as feeble-mindedness, for instance, will be gradually bred out of the racial stock.

Maternal Hygiene

Regardless of whether eugenic principles, positive or negative, ever become a prominent factor in health conservation, it is obvious that everything pertaining to the health of the mother must receive attention if real health advance for the nation is to be achieved. The health of the mother is so closely interwoven with the health of the infant that almost instinctively we associate the terms maternal and infant hygiene. And as Sir George Newman pithily put it: "Here is the source of the nation. From a physical point of view, what the mothers and children are the nation is and will be."

Child and School Hygiene

Passing beyond the period of infancy we find our hygienic nomenclature chiefly focused on the general term, child hygiene, and better to emphasize the methods by which child hygiene is to be fostered, such specialized terms as dental hygiene, school hygiene, physical hygiene or education, hygiene of nutrition and others not yet so familiar.

Passing on to adolescence and adult life still other terms are coming into wider use and into more intelligent comprehension by us as a nation. I refer to the terms mental hygiene, industrial hygiene, personal hygiene and all they imply. This list is not by any means exhaustive, but by this very terminology of the newer health program we apprehend clearly that back of them all must lie, first, education of the individual in hygienic principles and, second, an intelligent voluntary response on the part of the individual to this education if our health conservation program for the future is ever to be made effective. In fact, we may reasonably say that the health program of the future will be effective directly in proportion to the application of four fundamental factors each of which can only be suc-

cessful by the active participation of the individual citizen. These are, first, personal assimilation of the simpler principles of personal and community hygiene; second, personal volition or a will to put this knowledge into effect; third, an increased degree of self-control by the average individual with a corresponding increased ability to regulate by the rule of reason and moderation the ancient instincts of man whether they relate to sex, food, drink, pugnacity, work or sloth, or such mental instincts as fear, hate and envy, and fourth, an increasing instinct to regulate individual hygiene by the dictates of altruistic promptings toward our fellow men, which last may sound sentimental but in reality is coldly scientific as well.

Conclusion

The goal is now clear. It is to establish the span of average human existence upon the plane of the maximum average physiologic efficiency of the human body. Strictly speaking, up to the present time it has been only the very exceptional person who has lived a normal human life to its conclusion, for nearly all of us die prematurely. But now we know enough to change this; we know now that there is no such thing as an "inexorable law of mortality;" we know that "public health is purchasable and within reasonable limitations each community can fix its own death rate." We know that the classic statement of Babbage, "There are few things less subject to fluctuation than the average duration of life of a multitude of individuals," is absolutely erroneous and false when checked by the experience of our civilization for the hundred years that have elapsed since he laid down this once universally believed rule.

Obviously there is sufficient scientific knowledge extant, if intelligently and universally applied, to prolong the span of average human life by many years, and to make all these years much more abounding with the joy of living that accompanies top notch physical condition than is the case with the average person to-day. A committee of the American Public Health Association has recently reported that whereas average American life expectancy is now probably in the neighborhood of fifty years there is no insurmountable obstacle in sight of increasing that average expectancy by at least twenty years in the next two generations. Surely this is a goal worthy of our best endeavors.

CONSERVATION OF AMERICA'S ECONOMIC INDEPENDENCE

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THE title of these remarks was suggested long ago by a brief reference in the manifesto of the League of Nations Association, proposing that America surrender some of her economic advantages in the furtherance of the alleged cause of international good-will. It occurred to me at that time that no more unpatriotic or irrational proposal could possibly be advanced by those who were supposed to represent American interests in the discussions favorable to our joining the League of Nations, for, if there is any one duty, clear and emphatic, it is that we must conserve our economic independence, as much as we must leave nothing undone to conserve our political independence. To merge either or both into an international compact means the surrender of priceless privileges, for which we are under deathless obligations to a bountiful nature and the founders of the republic.

But in a much more serious sense we are in danger of sacrificing enormous economic advantages, by apathy, ignorance and greed. Our national resources have been and are being squandered at a ruthless rate, regardless of overwhelming evidence that we are not far from having reached the limit of safety. Of our imperial forest domain but a fragment is left to us, as a result of a scandalous policy of greed. Our coal-mining methods, in many respects, are crude in the extreme and priceless coal resources are forever being destroyed in the haste of making immediate gains, at the incalculable cost of future generations. In metal mining we are following a policy which is often destructive to the real interests involved, while in gold dredging we are destroying thousands of fertile acres, to be left a barren, rock-covered waste.

Nothing much of value has come of the conservation movement, in proportion to the enormous opportunities disclosed by early investigations of a decade or two ago. Our pulp supply is near the point of exhaustion, and practically nothing of real value is being done in the direction of reforestation. With the inspiring examples of certain European countries before us, our private and corporate forest policy still continues one of exploitation rather than of development.

Industrial waste has been the subject of countless essays and arguments, summarized in an extraordinary report prepared by a committee of the Federated American Engineering Societies

This report emphasizes the waste in printing, the waste in shoe manufacturing, in the manufacture of clothing, in the metal trades, in the textile trade and the building industry. It touches only the fringe of an immense question, but presents an unanswerable array of evidence, suggestive of the direction which we must take, if we are to preserve our economic superiority in the field of increasing international competition.

Among the evidences of a recognition of our duty in this respect, mention may be made of the admirable policy of the American Writing Paper Company to bring about standardization of products and processes in the manufacture of paper. Perhaps in no industrial field is there greater waste than in paper-making, printing and publishing, but happily few industries have more clearly recognized the urgent need of compromise upon standard sizes and standard qualities than these. It goes without saying that all needless waste is reprehensible impairment of our economic power. There is waste in water power, waste in wind and tidal power, waste of soil, and waste of water resources, which properly utilized would enhance the wealth and economic efficiency of this nation enormously. Bitter necessity will some day force us to adopt a more intelligent policy, but no necessity can replace natural resources and God-given opportunities that have been wasted and that are gone forever.

The waste of water-power is being recognized and some progress is being made towards the establishment of central power stations and distributing centers intended to serve the needs of rapidly growing population areas. The super-power project, which has been advanced to a point of practical consideration during the present year, is but one of many encouraging evidences of progress.

There is enormous preventable waste in our fisheries, and in the ruthless destruction of wild game, much of which has either vanished or is vanishing, never to be replaced. The last passenger pigeon died this year or last, a memorial to ruthless slaughtering of countless millions of birds, which might have served a useful purpose, if made a subject of rational economic and humanitarian conservation. The few buffaloes that remain are another sorry example of our apathy towards a policy of destructiveness which finds its explanation only in ignorance and greed.

In agriculture we are far from being as far advanced as we should be and the fertility of our soil is wasted by neglect in the prevention of soil erosion, all of which involves the destruction of priceless substances beyond the range of recovery. The amount of soil that is washed down the Mississippi River each year would, if

conserved, provide for countless millions for generations to come.

We are wasting our transportation possibilities by the precarious attention which we give to our vast inland river courses, subject to the changes of political fortune, or the expediency policy of political parties. What we need, perhaps, as much as anything, is a policy for the Mississippi River and adjacent waterways which will give us the cheapest mode of inland transportation at our command. We need also to provide rationally for terminal facilities, etc., so that we may reap the best possible results from investments which involve enormous sums of money.

We are wasting foreign trade opportunities by the precarious attention which we give to our great natural harbors, subject to fluctuating legislation, now liberal or parsimonious as the viewpoint of the party in power may decide. There are few more pressing problems than the development of a national port authority policy in strict conformity to our constitutional conception of the dividing line between government and private enterprise.

If we have been drifting with regard to rivers and harbors, we have been even more adrift with regard to a broad policy affecting the development of our national merchant marine. The costly experience during the war has left little of value in rehabilitating American shipping, and the outlook is not encouraging that the present and proposed subsidy legislation will meet the needs of a highly complex situation.

In one direction, at least, we have made most commendable progress and that is in the conserving of our internal banking power through the establishment of an efficient federal reserve system. We have not experienced since its organization the distressing panics of 1893, or of '67, or of '57, or of '47, as the case may be, but a deliberate policy on the part of the government safeguards the credit situation of the country, with reasonable effectiveness in times of emergency. The danger that confronts us at the present time is the dissipation of our banking power through foreign loans, insisted upon, in season and out, for the purpose of restoring foreign credit. Save in so far as we can legitimately extend liberal credit to Germany and Austria, until those afflicted countries are in a fair way to recover the millions of dollars loaned in nonproductive governmental undertaking, must impair our economic independence, while not advancing the economic restoration of the countries immediately concerned. All such proposals aim at making America pay for the war and suffer economic consequences that she should justly be relieved from.

There are two sources of economic waste, less definite of precise ascertainment, but nevertheless of the very first importance.

There is an immense and largely preventable waste of labor time, due to needless strikes and labor controversies otherwise, which a more rational policy on the part of the government and on the part of corporations would reduce to a negligible minimum. Strikes and labor controversies but symbolize industrial warfare, as needless and unjustifiable as is military warfare in international relations. The railway strikes and the mining strikes of the present year involved inconceivable amounts of waste in productive labor, aside from a vast amount of waste in economic materials. The work that isn't done can never be made good, for each day brings its own demands and each day should be made the best and the most of. The prevention of labor waste should be made a paramount policy on the part of the government and should be as consistently aimed at, as a matter of everyday duty on the part of large corporations, as the waste by lapses in life insurance has been prevented by improved methods of executive direction.

The labor waste involved in a needlessly large labor turnover has during recent years been materially reduced to the considerable advantage to all concerned. The principle has been recognized that too much has been sunk in making a man an efficient employee to justify his sacrifice upon the precarious mood of a possibly prejudiced superior official. In time there will be recognized a higher duty that the loyalty that is expected of employees towards the employing concern likewise demands an even higher sense of loyalty on the part of the concern toward the employee. The vast unemployment problem of recent times, affecting nearly all industrial countries, suggests the adoption of a policy, which I have elsewhere defined as the establishment of an "industrial depression reserve", which will safeguard the interests of workers during periods of involuntary idleness, due to causes or conditions beyond the control of both employers and employees.

Finally, there is the enormous waste attributable to ill health. Safety and sanitation in industry during the last few years have fortunately made great progress. One corporation alone—the United States Steel—has spent more than $70,000,000 during the last decade in improving the conditions and fostering the safety of its workers in countless ways. Our death rate at the present time is the lowest in our history, and it has reached a point which even a decade ago would have been considered absolutely unattainable. It is now less than half of what it was thirty years ago. Tuberculosis has been reduced more than one half and typhoid fever, once the scourge of young people, is now practically a thing of the past. In the southern states, malaria is rapidly diminish-

ing, and from every source come reports that a policy of effective health conservation is being opposed to the destructive influences that always have and always will threaten the life and the safety of mankind. While much has been done more remains to be done. Most of the health conservation has affected the younger ages, but gradually we are beginning to understand the conditions under which life may be prolonged considerably beyond the scriptural threescore and ten. Old age is unquestionably being attained to an increasing extent, while vigorous manhood now extends far beyond the earlier years, in which in the past failure of health and strength was a matter of common occurrence. Apparently there are no reasonable limitations which man may not hope to be able to overcome by intelligently adapting himself to his environment.

As thus conceived, our economic freedom involves the supreme duty of a consecrated sense of intelligent living and of the rational use of all the means that a bountiful nature has provided for us. Conversely, it implies the sinfulness of a policy of greed, apathy and ruthlessnecs, which sacrifices the present to the immense disadvantages of generations to come. If our fathers had managed as we are managing, this country to-day would be near to the European level instead of being the most prosperous and the happiest on the face of the globe. We shall fail or succeed in proportion as we realize our solemn obligation that the conservation of our economic independence is of equal importance with the maintenance of our political independence through a constitutional and republican form of government.

ON THE HISTORY OF PHYSIOLOGY AND SOME OF ITS LESSONS[1]

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TO deal adequately with the history of a science, such as physiology, one should be both a scientist and a historian. But at present the two functions are almost never found in one person. History, as ordinarily taught and practiced, is certainly the least scientific of all branches of knowledge. As a great scientist, Wilhelm Ostwald, in his lectures before the Rice Institute on the "Organization of Knowledge" has truly said, "the essence of knowledge organized as a science is the attainment of the power to control the future, or at least foretell its course."

Prophecy as practiced in science is not mere fortune telling to satisfy an idle curiosity, but guidance and direction for our acts and work. Astronomy foretells for the sailor the hours of the tides, the positions of the stars and for us all the occurrence of such events as eclipses and the passage of meteors. Some day it may even foretell the weather—and years ahead.

The prophecies of chemistry take the form of such conditional propositions as this: If you mix certain substances in certain proportions under certain conditions, you will get such an amount of such a product—be it rubber or leather or steel or dye. Physics likewise foretells that if we induce certain steam pressures in engines of a certain design, we shall obtain such an amount of power. Economics foretells that a rise of prices will result if too much paper money is printed. It is this power of conditional prophecy which is used to run trolley cars, and to light our homes and halls, and in general to make material civilization possible.

The history of science according to this view should be therefore not merely a chronicle of discovery, but an analysis of the relations of ideas and of methods to progress and the application of the conceptions thus gained to guide us in present and future work; for the fundamental idea of science—the idea which historians have not yet grasped, nor yet recognize as a duty even with

[1] The third of a series of lectures on the History of Medicine, by a number of lecturers, under the auspices of the Gamma Alpha Society of Yale University.

bleeding Europe before their eyes—is that in this world of nature and of man certain sequences of events continually recur, but never twice strictly and exactly alike, and that the business of organized knowledge is to define the principle of repetition, to show the extent and the reasons for the variations, and to suggest how mankind may mould the world to culture and civilization out of the "original sin" of nature.

When we face the topic of this evening with this idea in mind, the first consideration which presents itself is that in what we to-day call a distinct science, such as physiology, physics, or chemistry, we are speaking in reality of a strictly modern and ephemeral thing. Each has its roots and ancestors in the past, but so to speak, each makes itself out of the materials inherited from the past and ennobles its own ancestors. Moreover, each will probably in the future be divided up, its name transferred, or even forgotten along with astrology, alchemy and heraldry, and its various components recombined in other subjects whose names have not yet been even invented.

Such a subject as the physiology of A. D. 1922 certainly did not exist in 1822, any more than you and I existed then; and probably by 2022, our physiology will be with you and me and "yesterday's 7,000 years."

Before we go back to the past ages to trace the beginnings of physiology, we must define what particular conceptions and objects in the broad current of science we understand in A.D. 1922 under the word physiology. We understand two things, either or both of which enter into every problem in any of the various fields of physiology. May I illustrate by quoting from the recent Silliman lectures here by Professor Krogh? He was speaking of the physiology of capillaries and he said:

> As is generally the case in physiological research, we have a double purpose in studying the reactions of capillaries to physical and chemical stimuli: we want to find out the mechanism (in the broadest sense of that term) of every single reaction studied, and we want to find out also the meaning, the part played by the reactions in the delicate regulations by which the organism and the organs are adapted to the ever-changing environmental conditions.

The "mechanism" and the "meaning" of living creatures and their organs, these are the questions of physiology. It is because the mechanisms of living things are, as we now know, fundamentally the same as those of physics and chemistry, that we physiologists partake of the same heritage as physicists and chemists. We claim as part of the heritage of physiology Archimedes, with his ideas of levers and of specific gravity; Torricelli and his conceptions of the pressure of a column of liquid; Lavoisier and Liebig

and all those great names which are associated with the development of our ideas as to the conservation of energy and the indestructibility of matter. The very core of physiology lies in what we term metabolism, and the chemists term transformations of matter with no change of weight, and the physicists formulate under the laws of thermodynamics. From a mechanistic standpoint, Lavoisier was the greatest physiologist who ever lived and yet the chemists would certainly claim him as their own. But Lavoisier's work can not be divided into a physiological part and a chemical part. No, it was all chemistry and practically all physiology as well. Science is one, and I will venture the guess that perhaps one hundred years from now in a lecture here on the history of physiology, the lecturer may say, and say truly, that in the latter part of the 19th century there lived and worked in New Haven a physiologist as great as Lavoisier, a man who taught those principles of equilibrium in such chemical systems as the humors and cells of living organisms, upon which the ultimate explanation of life must rest—Willard Gibbs, a mathematical physicist.

Perhaps, some day in an infinitely distant future, physiology will thus be converted into a branch of mathematical mechanics. But when a problem of mechanism is solved, we still have before us, as Professor Krogh said in the passage which I quoted, the problem of the meaning, that is, as we say in physiology, the function of these mechanisms. Here we part company from physicists and chemists, for they utterly reject, or at least neglect, teleology nowadays. They can afford to; but in dealing with living things we must guide and check our work by teleological considerations or we may go far astray. As Aristotle put it 2500 years ago: "In dealing with respiration, we must show that this and that part of the process is necessitated by this and that other stage of it"—that is, its mechanism; and we must also "show that it takes place for such or such a final object."

On the other hand the standpoint of modern physical science regarding teleology is summed up in an anathema composed by Francis Bacon about 400 years ago: "To say that the hairs of the eyelids are for a quickset and fence about the sight; or that the firmness of the skins and hides of living creatures is to defend them from the extremities of heat or cold; or that the bones are for columns or beams whereupon the frames of the bodies of living creatures are built; or that the leaves of trees are for protection of the fruit; or that the clouds are for watering of the earth; or that the solidness of the earth is for the station and mansion of living creatures, and the like is well enquired and collected in Metaphysic; but in Physic they are impertinent."

For chemistry and for physics, and doubtless also for biochemistry and biophysics such conceptions are to-day "impertinent." But the formulation of such conceptions regarding the living body is the very essence of physiology proper, for the word physiology is derived from the Greek words *logos* and *phusis* or *physis*. It means the principles of nature; but *physis*, as Hippocrates used the word, means far more than nature: it is "the some thing working toward an end," the something which v.Leiden recognized when he said, "If you can only keep your patient alive long enough he will generally get well of himself." And here let me point out that no mere mechanism, such as an automobile, ever recovers by merely being left alone. In my experience even a broken spark plug always requires a surgical operation.

Now let us make a rapid survey of the great contributions both to the problems of mechanism and of meaning and see how they are related.

The mammalian circulation and especially the heart has probably been the object of more investigation than any other topic in science. Aristotle, whom Osler speaks of as the founder of physiology, as well as comparative anatomy, zoology, botany and some other sciences, recognized the heart as the central organ controlling the circulation, the seat of vitality, the place where the blood was finally elaborated and impregnated with animal heat. Aristotle did not distinguish between arteries and veins, but recognized that from the blood vessels throughout the body "the nutriment oozes like water in unbaked pottery."

A clearer view of some points, but not so on others, was reached by Praxagoras who taught in the celebrated University at Alexandria a quarter of a century or so after Aristotle. He recognized that only the arteries pulsate, but he taught that these vessels were really air tubes; only the veins containing blood. Hence he applied the word artery, which we still use, but which literally means an air tube like the wind pipe, the trachea, and bronchi. It was an odd mistake, but perhaps the following incident may suggest how Praxagoras happened to make it: Some years ago in connection with a lecture, I was demonstrating the anatomical relations of the heart and lungs of a big dead Newfoundland dog, when one of my hearers, a burly black bearded man, pointed to the aorta and asked what it was. I told him it was the great artery. "But," said he, "it never contains blood, for I have cut up many animals and have always found in it only air or a little bloody foam." Of course I was curious to know how he came to cut up many animals; and found that he was assistant Rabbi of an orthodox synagogue and that he koshered cattle, that is, cut their throats. Ap-

parently the dying gasps of an exsanguinated animal fill the aorta with air, as the Rabbi, and perhaps Praxagoras also, found, for the Bible tells us that koshering started in or near Egypt. Failure to appreciate the abnormal conditions in experiments on animals has led many modern investigators to almost equally erroneous conclusions in some of our problems.

The Alexandrians also described the valves of the heart, but it was 400 years later, that is, in the second century A.D., before Galen, the great Roman physiologist and physician, proved that the arteries contain blood. He did it by an experiment, not on a dead body, but on a living animal. He placed two ligatures a little distance apart upon an artery. "Now," said he, "if I cut the vessel, spiritus (or, as we would say, air) will come out, if Praxagoras is right; but blood if I am right in holding that the arteries are really blood vessels." Then he cut a nick in the vessel—just as every student doing a blood pressure experiment does nowadays to insert a cannula—and of course there was a little spurt of blood. But there he stopped and it was 1400 years before William Harvey, an Englishman, physician to King James the 1st, discovered and proved by ingenious experiments that the heart is a pump and that the blood runs in a circle.

It is extremely difficult for us to form a clear conception of some of the medieval beliefs regarding the living body and scientific matters in general, and I shall merely abbreviate here the account which Sir Michael Foster gives of the Galenic physiology.

The parts of the food absorbed from the alimentary canal were carried by the portal vein to the liver, and were there converted into blood, or rather the blood was there enriched with nutriment, or as it was termed "natural spirits." This crude blood, passed by the vena cava to the right side of the heart, and some of it filtered from the right ventricle through innumerable invisible pores in the septum into the left ventricle. As the heart expanded in its beat, it drew air from the lungs into the left ventricle. This mixture of blood and air by the help of the heat, which was innate in the heart, which was placed there as the source of the heat of the whole body by God in the beginning of life, and which remained there until death, was imbued with "vital spirits" while at the same time the innate heat of the heart itself was tempered and prevented from becoming excessive.

From the right side of the heart there was sent to the body generally along the great veins and also to the lungs a flow, followed by an ebb, of crude blood endued with natural spirits only, blood serving the lower stages of nutrition. From the left side of heart there took place also along the arteries to all parts of the

body a flow, followed by an ebb, of blood endued with vital spirits, and so capable of giving power to the several tissues to exercise their vital functions. It was the blood which the left heart sent to the lungs through the pulmonary veins which carried those fulginous vapors which, in the fermenting activity giving rise to the vital spirits, were extracted from the crude blood, and were finally discharged into the air in the lungs. The nutriment of the food which had been converted into natural spirits in the liver and transformed into vital spirits in the heart, finally reached the brain by way of the arterial blood and there generated the animal spirits, which, pure and unmixed with blood, were carried along the nerves to bring about muscular movements and other functions of the body.

All this sounds exceedingly crude in its conception of the heart and blood vessels, but it is still cruder in that which it omits, namely, in the lack of any conception of the energy liberating function, metabolism, the mechanism and meaning of respiration and the relation of the organism to the atmosphere. For all of this, as I have said, we have to wait until Lavoisier founded modern physiology less than 150 years ago.

It was not until near the middle of the 16th century that any one seemed to have grasped the true relation of the heart and lungs; then Michael Servetus, in a great theological work, with physiological illustrations, included a passage in which he announced that the blood, instead of filtering through the walls of the ventricles, is, on the contrary, pumped from the right heart to the lungs and, thus aerated and made bright by the passage, is sent into the left heart; there apparently he thought it stopped. It seems odd, almost humorous, that this physiological discovery should have been included in a work on theology, but humor gives place to thought when we recollect that Servetus was burnt at the stake for the religious views and doubtless also in part for the physiological views which his book contained; yet the beliefs of both sorts stated in that book were essentially what all educated people now hold; and the man who brought about his death was Calvin, the great founder of that movement in thought out of which to a large extent Puritan New England and Yale University took their origin. Evidently it is not always best even for very positive people introducing an important new idea to be too hasty in destroying those who differ with them.

Vesalius, the founder of anatomy, who also lived in the sixteenth century, thought it safer as regards the Galenic conception of the heart to speak as follows:

The septum of the ventricles, composed as I have said of the thickest substance of the heart, abounds on both sides with little pits impressed in it. Of these pits, none, so far at least as can be perceived by the senses, penetrate through from the right into the left ventricle, so that we are driven to wonder at the handiwork of the Almighty by means of which the blood sweats from the right into the left ventricle through passages which escape human vision.

As a reward of this caution, Vesalius escaped serious persecution and died in his bed. Anatomists have always been a quieter, less restless sort of people, with less desire for revolution and changes in the curriculum than have the physiologists.

We come now to William Harvey. There is little need to describe Harvey's conception of the heart beat, for it is almost word for word contained in every textbook of physiology at the present time. In most points regarding the heart itself this clear, simpleminded, straightforward experimenter attained completeness and perfection. His book, "The Motion of the Heart and Blood in Animals" is the most delightfully readable of scientific works and, as a good English translation of its original Latin is purchaseable in the cheap but serviceable Everyman's Library, every student in any branch of biological science should own and read it. When Harvey is read first hand, it becomes clearer than any lecturer can explain that it was the lack of knowledge of what we now call energetics and metabolism, physics and chemistry, and the real meaning of respiration which gave to his path its peculiar difficulty and limited his discovery. It is his merit that in the midst of the misconceptions of these matters which he could not and did not correct, he attained truth for his own special topic, the mechanism and meaning of the heart movements. He says:

When I first gave my mind to vivisections, as a means of discovering the motions and uses of the heart, and sought to discover these from actual inspection, and not from the writings of others, I found the task so truly arduous, so full of difficulties, that I was almost tempted to think with Frascatorius that the motion of the heart was to be comprehended only by God. For I could neither rightly perceive at first when the systole and when the diastole took place, nor when and where dilatation and contraction occurred, by reason of the rapidity of the motion, which in many animals is accomplished in the twinkling of an eye, coming and going like a flash of lightning; so that the systole presented itself to me now from this point, now from that; the diastole the same; and then everything was reversed, the motions occurring, as it seemed, variously and confusedly together.

His most difficult task, as is often the case in a discovery of the first rank, was to refute the errors and misconceptions of the time, and to free his readers from false modes of thought. He says:

Almost all anatomists, physicians, and philosophers, up to the present time, have supposed with Galen, that the object of the pulse was the same as that of respiration; that is, to cool the blood. But did the arterial pulse and

the respiration serve the same ends; did the arteries in their diastole take air into their cavities, as commonly stated, and in their systole emit fuliginous vapors by the same pores of the flesh and skin; and further did they in the time intermediate between the diastole and the systole, contain air, and at all times either air, or spirits, or fuliginous vapors, what should then be said of Galen's experiment showing that the arteries contain blood?

Having thus given his reasons for believing that the heart performs some function other than that of the chest and lungs in breathing, he proceeds to give the following description, the classic account of the heart beat:

At the moment the heart contracts, and when the breast is struck, when in short the organ is in its state of systole, the arteries are dilated, yield a pulse and are in the state of diastole. . . . The arteries, therefore, are distended, because they are filled like sacks or bladders, and not because they expand like bellows. It is in virtue of one and the same cause, therefore, that all the arteries of the body pulsate, namely, the contraction of the left ventricle; in the same way as the pulmonary artery pulsates by the contraction of the right ventricle.

All the points which these quotations assert were demonstrated by Harvey by numerous experiments and keen observations on living animals, on frogs, snakes, pigeons, fish, dogs and so on and also by experiments and observations on the veins in the arms of man.

Few figures in science stand out as originative and creative as Harvey and yet he has been criticized from two almost directly opposite standpoints. The points made are true but do not really decrease his merit. It has been shown on the one hand that the greater part of what Harvey wrote had been thought and suggested by others previously more or less clearly and that he got the germ and possibly even some of the form of his ideas when a student in Italy, for the Italian universities were at that time the living centers of thought in Europe. On the other hand, it has also been shown, particularly by the late Professor J. G. Curtis, who was profoundly versed in the physiology of the Greeks and Romans, that to a considerable extent Harvey himself was as much in the dark regarding the uses of the circulation as any of his contemporaries, and that he fell back upon Aristotle just as they did. Here he gropes and stumbles and fails; and as Curtis shows, the circulation in Harvey's mind apart from the physical movements of the heart was more Greek than modern. It had in it more of Aristotle than of Carl Ludwig.

There is no doubt that there is truth in both these comments upon Harvey. He drew on the knowledge contained in the literature of his time and was hindered or helped by what it lacked or contained just as we are now. It puts such matters in their true

light, however, to notice that the same sort of comments apply to nearly all the great discoverers; for instance, in the case of Christopher Columbus, it has been shown, I believe, both that others had discovered America before him and also that Columbus did not realize that he was discovering America. Neither Columbus nor Harvey nor any other great discoverer can possibly realize the enormous consequences which will grow out of his work, but this fact does not in the least decrease their greatness and the immensity of our debt to them.

Even with all the resources of modern laboratories, the problem of just how much blood the heart discharges at each beat is not yet solved much beyond the point at which Harvey left it.

In Harvey's day or shortly afterward, there lived in Italy two great physiologists, Malpighi and Borelli: intimate friends at first, but later disagreeing, Borelli vented his feelings on his colleague's scientific work in quite modern fashion. Malpighi was chiefly a great anatomist, and especially a histologist and as such his work has been described in a preceding lecture of this series, but he has this supreme interest for us that he was the first to turn the microscope upon the finer blood vessels of the circulation and thus to see the marvelous picture of the blood pulsating in arterioles, its corpuscles squeezing through capillaries, to be reassembled in the central column of the slow and steady stream of the venules. It is most significant that this discovery depended upon the use of the then new physical instrument of precision, the microscope.

Borelli was one of the first to accept Harvey's teaching and he explained more fully than Harvey had done the mechanics of the pulse. He recognized the part which the elasticity of the arteries plays in converting the intermittent discharge of the heart into a steady flow and first expressed the idea of the peripheral resistance of the circulation. Here again we find the association of physics and physiology. As a student Borelli had studied the writings and for a time had listened to the lectures of Galileo, the man who first recognized that the world revolves about the sun and who defined gravity and other physical conceptions. Borelli had associated with and been influenced also by Torricelli, to whom we owe our modern conceptions of atmospheric pressure and of the nature of a vacuum and the barometer.

It was in such an atmosphere that Borelli worked; a mathematician, a physicist and a physiologist. His greatest work was on animal motion. He treated the bones as levers and the muscles as motors and worked out correctly many of the mechanical movements of the body and limbs, as well as of the viscera. Much of what he said is as true to-day as it was when he wrote it. He also

dealt the death blow to that idea of a "spiritus" or air, which was supposed to be blown by the brain through the nerves, then believed to be minute tubes, to the muscles, inflating them and thus causing their contraction. His crucial experiment, which, as he expressed it, "does away with all this nonsense about spiritus" he describes thus:

When the muscles of a living animal are divided lengthwise, while the animal is submerged under water, and in consequence of the pain is struggling violently, in the midst of such great copious fervor and ebullition of the supposed spirituous gas which would thereby be excited in the muscles, one would expect that innumerable bubbles of gas would burst forth from the wound, and ascend through the water; whereas nothing of the kind takes place.

You will all recognize the soundness of this experimental method of locating an air leak.

About the time that Borelli died in Italy, another remarkable man was born to carry on his work. Born in England, Stephen Hales was a younger son of an English country gentleman and, as was the custom of younger sons, he turned to the church for a living. He studied at Cambridge and obtained a B.A., M.A., and B.D. and later, from Oxford, an honorary D.D. In college he did many dissections and repeated the experiments, the scientific novelties of that day, by which Boyle had been led to the gas law which bears his name. Later Hales lived the life of an active country clergyman, but he seems to have thought the glory of God was best demonstrated by revealing the wonders of nature, for few scientific men of that time have as long or as valuable a list of experimental investigations as has Hales. He died in his 83rd year and his monument is in Westminster Abbey; in fact, he was a very eminent man. He was extraordinarily modern minded, for in practically all his work he used accurate quantitative methods and his employment of the word "equilibrium" in the following definition of health would be creditable in 1922. He says:

As the healthy state of the animal principally consists in the maintaining of a due equilibrium between the fluids and solids, it has ever since the important discovery of the circulation of the blood been looked upon as a matter well worth inquiring into to find the force and velocity with which these fluids are impelled; as a likely means to give considerable insight into the animal economy.

Accordingly, he performed the celebrated experiment which bears his name and which he describes as follows:

In December I caused a mare to be tied down alive on her back; she was 14 hands high and about 14 years of age; had a fistula on her withers; was neither very lean nor yet lusty; having laid open the left crural artery about three inches from her belly, I inserted into it a brass pipe whose bore was one-sixth of an inch in diameter; and to that, by means of another brass

pipe which was fitly adapted to it, I fixed a glass tube, of nearly the same diameter which was nine feet in length; then untying the ligature on the artery, the blood rose in the tube eight feet, three inches perpendicular above the left ventricle of the heart . . . . . when it was at its full height, it would rise and fall at and after each pulse two, three, or four inches. . .

This was the first accurate measurement of arterial pressure.

Thus far we have talked mainly of the circulation because in this brief summary of the history of physiology, we are omitting mere chronicles of false and misleading ideas and are selecting as the origins of our science those ideas only which were and are true or which have led to truth. Under this rule, there is little to say of the chemical side of physiology down through Greek, Roman, and medieval times. The alchemists were as furtive as our forgers, for alchemy was a crime close to witchcraft, an offence for which one was burnt at the stake. Thus when that amazing figure, Theophrastus Bombast von Hohenheim, also called Phillipus Aurelius, and commonly known as Paracelsus, who is said to be the original of Goethe's Faust, first introduced chemistry to physiology, along with opium, hydrochloric acid and other new drugs and chemicals, he also brought the mystical idea that over each reaction presides an archeus, a "spirit called from the vasty deep" to control it. From these Archei our digestive and other ferments are descended, and perhaps the vitamines belong in the same family. It is difficult to find an easily quotable passage to give an idea of what an Archeus was in the mind of an alchemist facing a problem in biochemistry. But a great modern thinker and writer who was also a thoroughly medievally minded man, the late Cardinal Newman, has expressed essentially the same idea in these wonderful words:

He is speaking of his opinions of angels and he says:

I viewed them not only as the ministers employed by the Creator in the Jewish and Christian dispensations, as we find on the face of Scripture, but as carrying on as Scripture also implies the economy of the visible world. I considered them as the real causes of motion, light and life, and of those elementary principles of the physical universe, which, when offered in their developments to our senses suggest to us the notion of cause and effect, and of what are called the laws of nature. . . . . What would be the thoughts of a man who when examining a flower or a herb or a pebble or a ray of light, which he treats as something so beneath him in the scale of existence, suddenly discovered that he was in the presence of some powerful Being, who was hidden behind the visible things he was inspecting, who, though concealing his wise hand, was giving them their beauty, grace and perfection, as being God's instrument for the purpose, nay, whose robe and ornaments those objects were, which he was so eager to analyze. . . . . Every breath of air and light and heat, every beautiful prospect, is, as it were, the skirts of their garments, the waving of the robes of those whose faces see God.

As a further illustration, I am reminded of some words of St. Augustine which I came across in his Confessions not long ago and which show the medieval attitude toward scientific investigation. He was discussing the nature of time. Time, he said, may be measured as the duration needed to read a certain number of verses, or to walk a certain distance. What will be its end, he asks. Obviously the Judgment Day. What was its beginning? Obviously the morning of the first day of creation. But what, he asks finally, was God doing before the creation? And he answers by saying that, according to the best authorities, God was then engaged in preparing Hell for those who inquire too closely into his mysteries.

Following Paracelsus came von Helmont who was half modern and half medieval. He invented the word gas and to a considerable extent the conception for which it stands: an enormous service, for he described correctly to a great extent the formation of carbon dioxide in the fermentation of grapes, from which idea, as you will see, by slow gradations has come our idea of respiration. Of gastric digestion he said: "If the ferment were only an acid, vinegar alone would be able to transmute a mass of bread and be sufficient for the transformation of all our food." A ferment he described as "a specific gift of vital nature." He says also that the acid chyle passing from the stomach into the duodenum immediately acquires a saline nature, and changes from an acid into a salt, "just as vinegar by the addition of nimium (lead oxide) is changed into an aluminous sweetness." In the intestine a further change in the food materials is brought about, as he expressed it, "through a more excellent vigor of transmutation." He still believed in the Archeus, a sensitive soul, as the controlling agent in all bodily acts; but he was sufficiently modern to try to determine the location of the soul by experimental methods. Thus he made the seat of the Archeus not the brain, but the pylorus of the stomach; and for this he gives three reasons: first, a great emotion is always felt in the stomach; second, a man's head may be blown off by a cannon ball and his heart continues to beat for a short time; but third, his heart is instantly stopped by a blow in the stomach.

Following von Helmont in the next generation, Francois duBois or Sylvius discarded the Archeus and expelled spiritualism from biochemistry. Like a modern biochemist he held that if we had complete knowledge of the chemical reactions between acids and alkalis, life itself would be explained. But he also made just the sort of mistake that a modern biochemist knowing much chemistry and little biology makes: he saw gas bubbles rise in fermenting

dough and also in a vessel into which he had put carbonate of lime and hydrochloric acid, so he inferred that the chemistry of the two processes was identical. Sylvius assigned great importance in digestion to saliva, and one of his pupils, DeGraaf, among other important work, was the first to insert a cannula in the duct of Wirsung and to collect pancreatic juice. Both Sylvius and DeGraaf held that the juice was acid.

Space prevents my telling of the contributions and ideas of Stahl, Boerhaave and the great Haller who wrote a text-book of physiology in eight large volumes in Latin. One of the most concrete experimental additions to our knoweldge of digestion dating from this time was made by Réaumur. He fed a kite, a sort of hawk, with metal tubes with wire nettings over their ends containing meat. When the kite, according to its habit, regurgitated the tubes from its stomach, Réaumur noted that the meat had been dissolved out. The diet proved, however, too much for the kite, and its death ensued. Réaumur then carried on the same sort of experiments on dogs, showing the solvent action of gastric juice, which he was the first to obtain by placing pieces of sponge in the little metal tubes which he gave his animals to swallow, and which he obtained again from their stomachs.

Réaumur's line of experimentation was later continued with much industry and ingenuity by Spallanzani in Italy. But the extent of the knowledge gained is shown by the report which Spallanzani obtained from one of his colleagues, the professor of chemistry, who analyzed for him a sample of gastric juice. The chemist reported that "the fluid contains first pure water, secondly a saponaceous and gelatinous animal substance, thirdly salammoniac, and fourthly an earthy matter like that which exists in all animal fluids. It precipitates silver from nitrous acid and forms luna cornea. This phenomenon might induce us to suppose that common salt exists in the gastric juice; but the salt contained in this fluid is not common salt but salammoniac."

Now we approach the nodal point where the major lines of chemistry, physiology and physics unite to radiate again into the broad field of modern science. At the very center of the node we find Lavoisier. But first a few words of the men whose work he interpreted.

For the chemist the problem was the nature of combustion; for the physicist, it was the origin of the heat and power liberated; for the physiologist, it was the meaning of respiration and the source and mode of the heat and power of the living body. That respiration was the very essence of life even the Greeks fully realized, but they had scarcely any conception of the physical character

of a gas or the chemical differences between various gases. But let us be modest in our knowledge, for among the students of to-day an easy comprehension of the nature of gases and their laws is so rare as to be almost a special gift.

It was Robert Boyle who in 1660 took the first great step by showing by means of the air pump that in a vacuum a candle is extinguished and a mouse or sparrow dies. Seven years later Robert Hooke showed that it is not the movements of the chest which maintain life, but the passage of air through the lungs, for after opening the thorax of a dog, and making a number of small holes in the lungs for the air to escape through, he blew a constant strong current of air into the trachea, and life was maintained. At nearly the same time Lower demonstrated that it is the aeration of the blood in the lungs which causes the change of color from the dark maroon of venous to the bright scarlet of arterial blood, and he even sensed the relation of respiration to combustion, for he says of the need of fresh air, "were it not for this, we should breathe as easily in the most filthy prison as among the most delightful pastures"; and again he says: "where a fire burns readily, there can we breathe easily." Lower was an Oxford man.

So also was Mayow, whose attention was caught by the part which nitre plays in giving to gunpowder its power. Following this lead through ingenious experiments, he came to the conclusion "that this air which surrounds us, and which since by its tenuity it escapes the sharpness of our eyes, seems to those who think about it to be an empty space, is impregnated with a certain universal salt, of a nitro-saline nature, that is to say with a vital, fiery, and in the highest degree fermentative spirit." This of course was oxygen. He recognized that burning and breathing were essentially identical and that the part of air essential to life is absorbed by the blood as it passes through the lungs. He almost sensed the nature of carbon dioxide also. But Mayow, Boyle, Lower and Hooke died and left no successors. The great Oxford school of physiology ceased for nearly 200 years, to be revived brilliantly by Haldane in this same field of respiration in our own day.

In the years following the English school, George Ernest Stahl, working at Weimar, Halle and Berlin, and making indeed valuable contributions, yet did more harm than good by his celebrated theory of phlogiston. He defined phlogiston as the essence of fire, for he conceived fire as a material thing. When any substance was burned, such as a piece of carbon, or when a metal was oxidized, the process was considered by Stahl to consist in the escape of phlogiston. When an oxide was reduced, phlogiston was, he thought, imparted to the metal. Thus physically phlogiston was a

sort of pseudo energy; chemically it was the antithesis of oxygen. This was altogether the most harmful error that has ever occurred in science. It utterly obscured the chemistry and energetics of respiration.

About the middle of the 18th century, Joseph Black, professor of chemistry at Edinburgh, identified what he called "fixed air," and which as he found comes off when limestone is calcined, in other words, carbon dioxide. He also showed that this fixed air is produced by fermentation, by burning charcoal, and that it is given off in the air expired from the lungs. He identified it in each case by the precipitate, or white cloud, which "fixed air" produces when blown through lime water.

About this time also Joseph Priestley first prepared oxygen. He had early found that air made irrespirable by burning a candle in it could be made again respirable by growing a green plant in it. In 1774 he made oxygen gas by heating oxide of mercury and showed its properties; but he was unable to free his mind from the phlogiston theory. He called breathable air "dephlogisticated air" and air rendered irrespirable by burning a candle in it he called "phlogisticated air." So, too, venous blood he considered to be blood laden with phlogiston which it gave off in the lungs where it came in contact with dephlogisticated air. His whole conception of combustion and of respiration was thus a completely inverted image of the truth.

Meanwhile Scheele, a struggling apothecary but a man of genius, in Sweden, was doing independently the same type of experiments, and expressed his conception of respiration in the suggestion that "the blood and lungs change fire air into acid air."

Now we come to Lavoisier, a master figure in three sciences: chemistry, physiology and physics.

Lavoisier was a rich tax collector for the French government and as such was connected with the Treasury. Gold is the one thing in respect to which weighing with fine balances is most important, and the association of Lavoisier through tax collecting with the art of weighing accurately was probably of critical importance in guiding his genius. Through the inherent intuitional power of his mind he assumed as no one else had done, and he proved, that matter can neither be produced nor destroyed as it passes from one form to another and that the one chemical property which is indestructible is its weight. He found that a reaction occurring inside a closed glass vessel involves no change of weight, and, as he said, "the usefullness and accuracy of chemistry depend entirely upon the determination of the weights of the ingredients and products both before and after the experiment."

Thus he established the major principle of modern chemistry. With his associate, LaPlace, he also constructed an ice calorimeter and determined the amount of ice which was melted when a given amount of carbonaceous material was burned in it. Thus for physics he laid the cornerstone of thermo-dynamics. For physiology he revealed the association of respiration and animal heat, for he put a guinea pig into the ice calorimeter and found that it produced 224 grams of "fixed air" (carbon dioxide) while melting 13 ounces of ice, and that these figures agreed fairly closely with those obtained when carbonaceous material was burned. At the same time he found that the animal consumed an amount of "eminently respirable air" or "air pur" (that is oxygen) such that the respiratory quotient (carbon dioxide exhaled divided by oxygen consumed) was 0.84. Thus he made a long step toward the idea of the conservation of energy as well as the nature of animal heat; and the meaning of respiration was revealed.

Lavoisier freed chemistry and physics from the phlogiston theory; he showed the real nature of oxygen, to which he gave its name, and the part it plays in combustion. His crowning experiment was a complete determination of respiratory metabolism upon man with and without food and during various amounts of work, which he found involved a fourfold increase in the consumption of oxygen above that in the resting condition. His reflection on this is interesting, for he said:

> This kind of observations suggests a comparison of forces concerning which no other report exists. One can learn, for example, how many pounds of weight lifting correspond to the effort of one who reads aloud, or of a musician who plays a musical instrument. One might even value in mechanistic terms the work of a philosopher who thinks, the man of letters who writes, the musician who composes. These factors which have been considered purely moral have something of the physical and material which this report allows us to compare with the activities of the man who labors with his hands.

What he would have done had his life not been cut short may be gathered from the following passage, the conclusion of his last communication to the Academy:

> Up to the present time we have learned only to conjecture as to the cause of a great number of diseases and as to the meanings of their cure. . . . Before hazarding a theory we propose to multiply our observations, to investigate the phenomenon of digestion, and to analyse the blood both in health and disease. We will draw upon medical records and the light and experience of learned physicians who are our contemporaries, and it will be only when we are thus completely armed that we will dare attack a revered and antique colossus of prejudice and of error.

But the storm clouds of the French Revolution were gathering. Then as now, as always, after war and revolution, the scientific

man who dares to think for himself is the inevitable victim of another type of man, the type of Marat, vulgar, aggressive, intolerant, the self-appointed agent of the new thing whether in government or in education. Lavoisier was sent to the guillotine. Doubtless always on great stages and on small, when the Marat type succeeds in grasping power for the short time that such men can be tolerated, their instinctive and first act will be to destroy those who guide their steps by a love of honor and of truth.

Were physiology merely biochemistry and biophysics, here I might stop. But there is yet another name which, although it came in the nineteenth century, stands out so preeminently as neither merely biochemist nor biophysicist but as a physiologist par excellence, that I must say in closing a few words about him—Claude Bernard.

With methods as simple for the most part as those available in the centuries preceding him, he revealed to us the vasomotor nervous system, the glycogenic function of the liver, the regulation of animal heat—the nature of carbon monoxide asphyxia—to mention only a few of the greatest of his achievements. It is not, however, to these particular discoveries that I wish to point attention, but rather to a general idea which is in danger of being lost sight of nowadays in the enthusiasm for the solution of the problems of mechanism.

It is to Claude Bernard that we owe particularly the conception of regulation: the organism as a dynamic equilibrium, the organism as a whole, the organism in control of its environment. It is in such lines of thought, originating with Aristotle and coming down through DesCartes, that physiology as physiology must be carried on by physiologists after biochemistry and biophysics have established themselves as sciences in their own right. Theirs are the problems of mechanism in the narrower sense, for physiology there remains the more general problem of living creatures as a whole and the coordination of their organs. It will be the service of biochemists and biophysicists to show, as Aristotle said, how "this and that part of a process (chemical or physical) is necessitated by this or that other stage of it." It is for physiology proper to study what Hippocrates called "physis," and as Aristotle also said "to show that this and that process takes place for such and such a final object."

This is not vitalism. It is organicism. In biology a mechanist is like a mechanic whose attention is fixed on wheels and valves and bolts. A physiologist must not be like such a mechanic, but rather like an engineer who views the organism as a whole, both in the interplay of its parts, its integration, and in its exterior relations,

the organism in its environment. This is a field in which we cannot perhaps expect for centuries still to come to attain wholly chemical and physical explanations. Three great examples in the recent development of such physiology occur to me: Pawlow's "Work of the Digestive Glands," Sherrington's "Integrative Action of the Nervous System," and Haldane's "Respiration." Each is founded on the best physics and chemistry available, but each goes far beyond the physics and chemistry of the present day in showing correlation and regulation.

This conception of physiology was defined by Claude Bernard as a study of the body's capacity to "preserve constant the conditions of life in the internal environment. It is a conception which has been termed organicism. It prompts us to the most thorough analysis of which biochemistry and biophysics are capable into the problems of mechanism, but it looks on this analysis as a mere preliminary and sees as the essential topic of the physiologist those living reactions and processes by which (expanding Claude Bernard's statement) "the organism preserves constant" or rather adjusts, controls and regulates within narrow limits of variation, such "conditions of life" as osmotic pressure, hydrogen ion concentration, temperature, content of sugar, calcium and potassium, and a thousand other elements already known, suspected, or yet to be discovered "in the internal environment."

THE STRENGTH OF THE CHIMPANZEE AND ORANG

By JOHN E. BAUMAN
ALLENTOWN, PA.

THE writer had so often noticed that, while all authorities on the anthropoid apes judged them to be greatly the superior of the human being in strength, no exact tests of their strength were cited, so that it seemed to him that even a few definite strength tests would be of interest and value.

Accordingly he made an attempt to obtain such tests by the use of a dynamometer used for testing the back and leg strengths of college students for anthropometric records.

The difficulty in getting the apes to make a fair test of their strength was found to be great. In the first place, the apes showed fear of the glisten of the metal of the apparatus which deterred them till they got used to the latter and found it harmless. In the second place, after the anthropoids had thus got used to the apparatus they quickly lost interest in it.

There thus proved to be but a few hours' interval in which tests of any value could be obtained. By attaching ropes to the apparatus, there was no difficulty in getting the apes to pull, but they would pull cautiously to see if the apparatus was loose, and when they found it firm they would stop pulling long before their maximum effort had been reached. Endeavors to tempt the apes into a maximum pull by having a man hold the rope, with the idea that the anthropoids would try to pull it out of his hand, did not accomplish what was desired, since the apes let go, or at least ceased pulling strongly, as soon as the man loosed his hold on the rope. The apes likewise had a tendency to try and jerk the rope instead of making a strong smooth pull. These jerks looked vigorous, but the dial of the recording device showed records of only one hundred to two hundred pounds.

Unexpected good fortune, however, attended the first trial with "Sister Suzie" Suzette, a highly trained adult female chimpanzee who formerly was a circus attraction, being a good bicycle rider and an adept at roller skating. She has recently attracted some notice because of her being the only chimpanzee to have had two "children" born to her while in captivity, Boma being the father. Both of these infants died within a few weeks.

CHIMPANZEE "SUZETTE"
With arms shaven for state performances before her entry into the N York Zoological Fark

The increasing treacherousness and meanness of Suzette's disposition was the factor that finally compelled her owner to retire her from circus life and place her in the New York Zoological Park, where the strength tests in question were made.

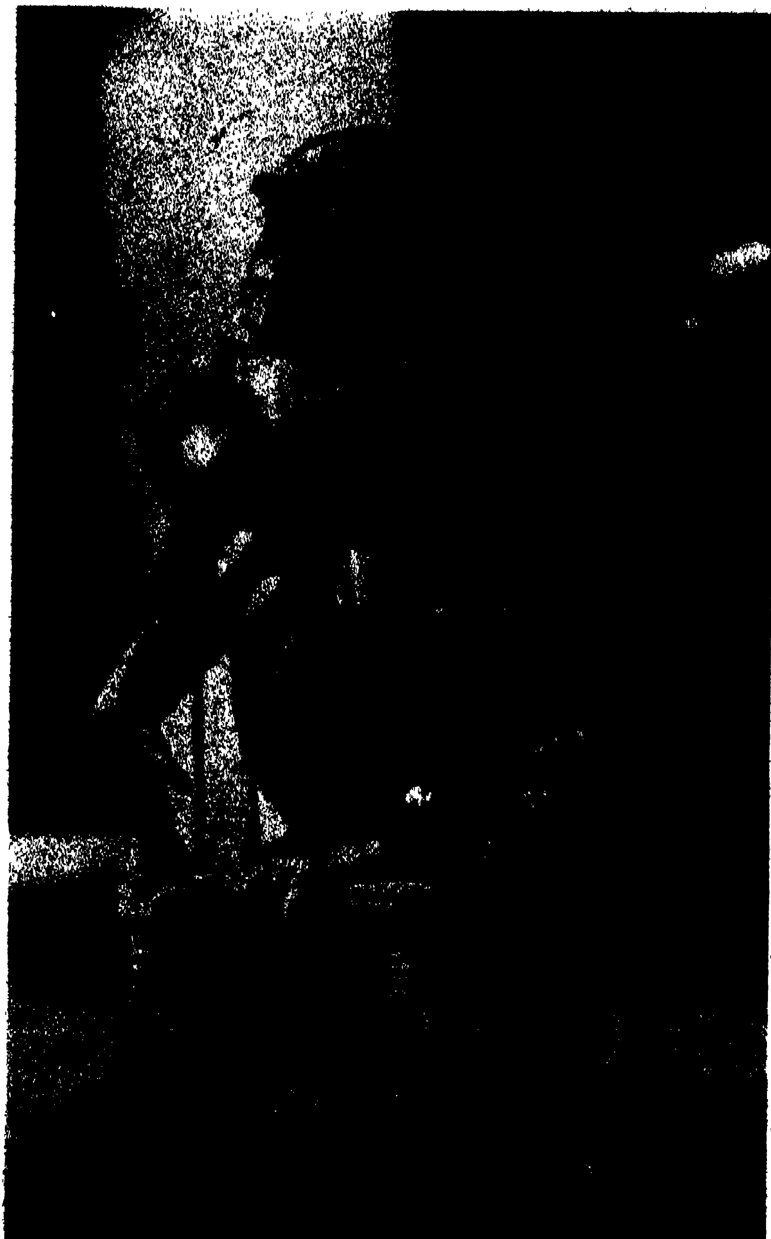
It is interesting to observe that it was Suzette's tricky and malicious disposition which caused the first test with her to be a complete success. As the writer had just finished fastening the chain that held the opposite end of the apparatus firmly to the steel frame several feet in front of the cage, Suzette, evidently fancying that she had the handlers of the apparatus at a disadvantage and could pull it to pieces, sprang at the rope and, bracing both feet against the bars, pulled back with both hands upon the rope, making a pull on the latter that recorded 1,260 pounds upon the dial of the recording device.

The viciousness of this pull was something remarkable, and in strong contrast to the half-hearted attempts of the orang tested just before this, as well as of Suzette's own subsequent attempts after she had learned that she could not tear the apparatus loose or smash it. Everything about the manner of the pull, as well as the set of the muscles of the ape's body and face, indicated a pull of maximum intensity. After the first pull Suzette refused to really exert herself, although she made one two-hand pull of 580 pounds without appearing to make a noticeable effort. She also made a number of jerks and moderate pulls ranging from one hundred to two and three hundred pounds.

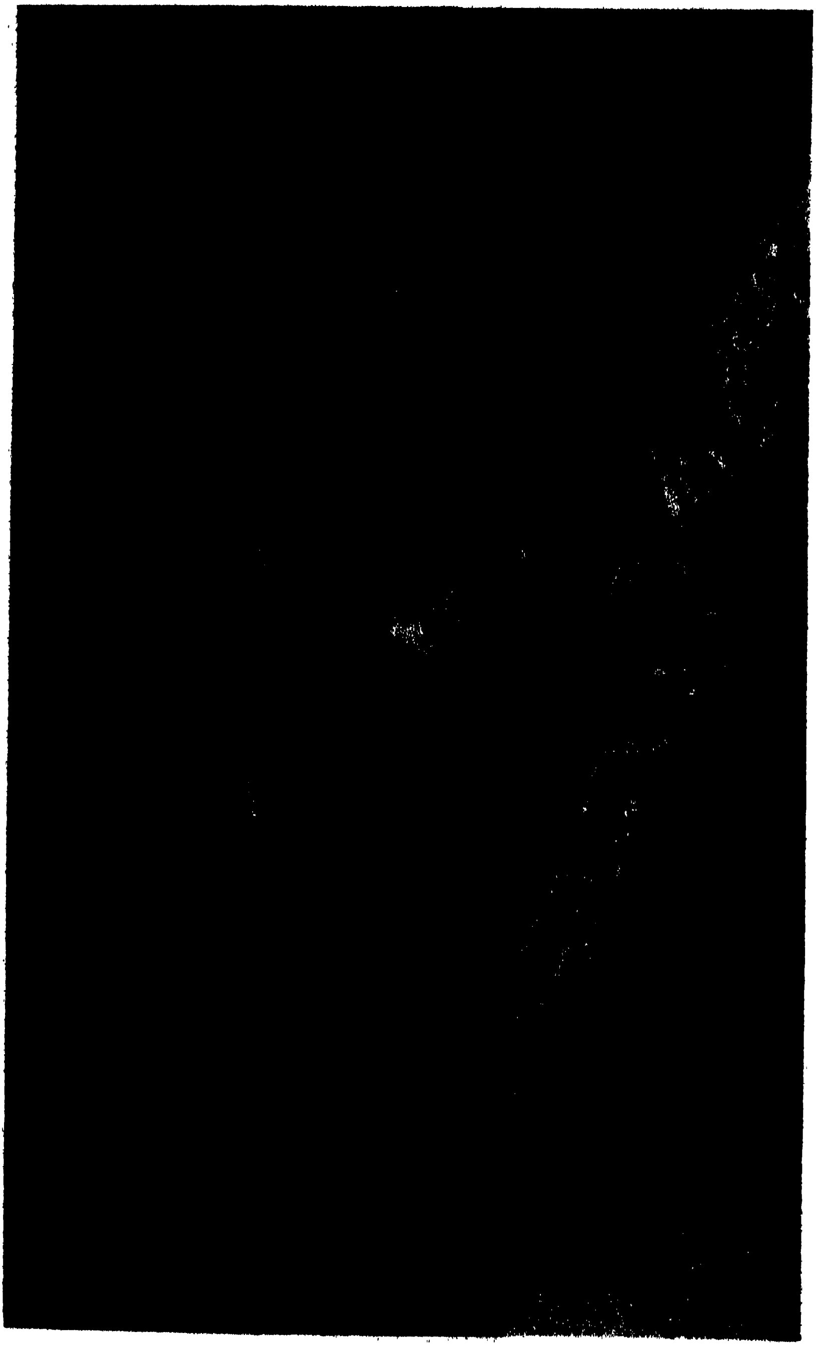
A point of interest in interpreting Suzette's greatest effort lies in the fact that she had both legs considerably bent at the knee, so that a muscular effort, to keep them from bending farther, of 1,260 pounds must have been made during the maximum of the pull. It has often been estimated that from the waist down the chimpanzee is hardly superior to the human being. According to the tape-measure, this would seem to be true, but the recording device tells another story. To the fingers the anthropoid's thigh muscles feel if anything firmer than the back muscles.

An average college student of Suzette's weight, 135 pounds, can pull in an approximately similar position and manner but 332 pounds, while one out of every hundred students can thus pull 500 pounds. Therefore Suzette's superiority on the basis of weight is in the ratio of more than three to one, while it would be an exceptional college student of any weight whose record she could not easily double.

Judging from appearances, the strength of the arms and shoulders of Suzette must be still more superior to that of the human being than is that of her back and legs. She made a few



CHIMPANZEE SUZETTE AT THE NEW YORK ZOOLOGICAL PARK



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approximately one hundred pound pulls, or rather jerks, with her teeth on the rope, and the writer hoped to get some data on the strength of her massive neck, but she would not make a fair test; in fact, had she tried she would almost certainly have cut the rope to pieces with the grip of her teeth.

No tests of any kind could be made upon Fanny, another female chimpanzee, for she refused to have anything to do with the apparatus.

Boma, said to be the largest chimpanzee at present in captivity and whose weight is estimated at 165 pounds, is such a splendid specimen of muscular development that it was disappointing not to be able to coax him into a two-handed pull by hook or crook.

A good one-hand pull which certainly closely approached his maximum was secured. During this pull the ape braced both feet on the floor of the cage and held on to a door leading into the next cage with his left hand while he pulled back upon the rope with his right as hard as he could, all his bodily and facial muscles testifying to the effort being made, although the sharp viciousness of Suzette's maximum effort was not in evidence in the manner of making the pull.

The recording device showed a pull of 847 pounds. After this tremendous pull, the ape made a 640 pound right hand pull without showing a very noticeable effort, and later several pulls ranging from 450 pounds to 200 pounds, which seemed quite easy for him. After this he lost interest and would make no further pulls. (In connection with the above the question suggests itself, what could a 450 pound gorilla do?)

It is worthy of note that in all his pulls except the lightest, Boma used the right hand in preference to the left. Under ordinary circumstances the writer has observed that, although to a certain extent ambidextrous, both the orangs and the chimpanzees when they wish to make an exceptional effort use the right hand in preference to the left.

It would be interesting to learn whether an adult male chimpanzee or orang could tear the scalp by seizing a human being by the hair as depicted in Edgar Allan Poe's imaginary account in the "Murders in the Rue Morgue." The writer always in the past regarded this feat as a grotesquely impossible figment of Poe's imagination, but an eight hundred pound pull is certainly a pretty strong one and it is possible that under such a strain the scalp might tear.

No results could be obtained with a young female orang, "Windy," and only two 140 pound one-hand pulls from the young 95 pound male orang "Dempsey," a result which no one who like

the writer has tried to pull a strap out of Dempsey's clutch and been hauled up against the bars by his slender sinewy arms will believe is his maximum strength of pull. In this connection it is worthy of note that the strength the orang and chimpanzee can exert is far greater than their girth of muscle or the latter's firmness would lead one to expect.

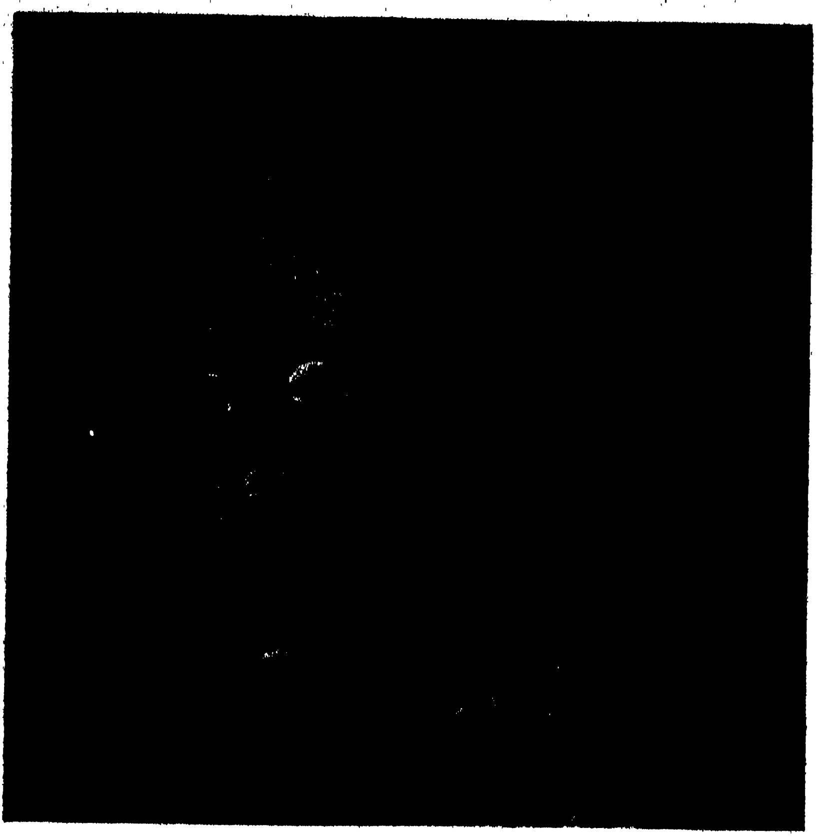
Only one attempt at hand grip tests was successful, and this recorded 64 kilos for Dempsey's right hand and several following attempts of 55, 35 and 25 kilos, respectively. Sixty-five kilos would be equal to that of a fairly strong man and may approach Dempsey's maximum, although the writer from his experience of Dempsey's clutch on his own wrist is inclined to believe this sinewy, lovable little orang could do better than 65 kilos on occasion. Boma's hand is so broad and mighty that his power of grip must be something tremendous, but no way of making a test was evident, since even if he could have been induced to hold the hand-grip dynamometer properly, Boma would even in a light effort unquestionably have surpassed the capacity of the apparatus, whose maximum reading is 100 kilos, the dial being graduated according to the metric system.

In closing this account, the writer wishes to take this opportunity to heartily thank the director of the New York Zoological Park, Dr. W. T. Hornaday, the veterinary of the Garden, Dr. W. Reid Blair, and the keepers of the primate house, Messrs. Palmer and Rawlinson, for their kindness in making possible the above tests and their invaluable aid in carrying them out.

Also hearty thanks are due to the authorities of Muhlenberg College for the loan of the pull test apparatus, and to those of Lehigh University, the second Alma Mater of the writer, for the loan of the hand-grip dynamometer used in the foregoing tests.

The writer would like to suggest that if any one desires to make further investigations in strength tests, the best results will in his opinion be secured with specially constructed apparatus which will have a dull finish so as not to remind the apes of the glisten of a revolver, of which latter they are ludicrously afraid. Such apparatus, to secure the best results, should have a powerful steel spring which can hold the ape's greatest possible pull and yet give just enough to make the anthropoid think that something is yielding and that it is worth while for him to pull to the limit of his capacity because it feels as though something might tear if he only pulls hard enough.

Further, large-sized rings like the well-known "flying rings" of the gymnasium or even larger would be apt to prove a very much better means of securing a maximum two-hand pull than the wooden handle, which the writer was forced to discard because

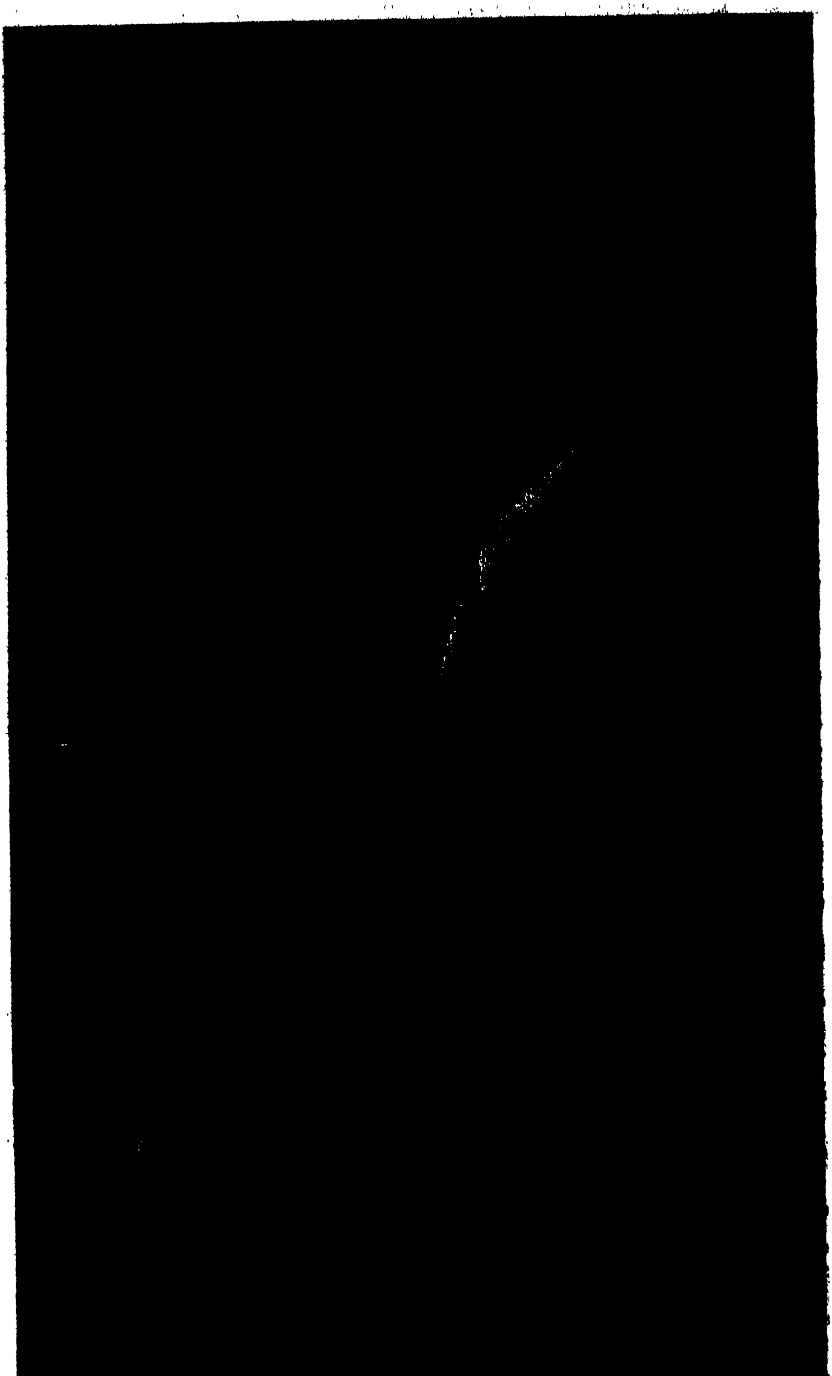


FACE OF THE ORANG-UTAN

of its getting twisted up in the bars by the apes not holding it properly or than the simple looped rope on which he later relied.

The recording apparatus had better be concealed from the anthropoid's view, since it often seriously distracts his attention from the pull. The rope to which the ring is attached should be just long enough for the ape to stand behind the bars and brace against them with his feet; if it be longer than this he either lacks purchase or pulls sideways with loss of power where the rope bends around the bar.

A hand-grip dynamometer should be a simple oval ring, with the recording device boxed in under cover of glass or celluloid, and a chain attached to one side of the ring, so that when the ape clutches the latter firmly to prevent the testers from pulling it out of his hand by the attached chain, the exact position of the ring in his hand will be immaterial and he can not tamper with the recording device.



WILHELM KONRAD VON ROENTGEN

Whose death is announced from Munich. Professor Roentgen's discovery of the Roentgen or X-rays in 1895 began a new era in the development of the physical sciences.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson
Science Service, Washington

JOB WANTED FOR FURFURAL

A new material has come into the market and wants to make itself useful if any one can show it how. Its name is "furfural"; queer sounding, but not so hard to pronounce as most chemical terms. The public is lucky to be let off with only three syllables and those slipping easily off the tongue.

Two years ago furfural was selling at $30 a pound. Or rather this was the price it was quoted at in lists of rare chemicals. Really it was not selling at all, except when a professor wanted a little vial of it to put into his museum case of organic preparations.

But it is now known that the stuff can be made cheaply from materials that are going to waste in unlimited amounts, such as corn cobs, oat hulls, straw and the like. Consequently, furfural is now quoted at twenty-five cents a pound and could be made very much cheaper, perhaps six cents a pound in a large scale plant, one capable of taking in, say, a hundred tons of cobs a day and turning out six tons of furfural. All that is needed is to cook up the cobs with steam.

I saw it done at the Color Laboratory of the Department of Agriculture, on the Arlington Farm, just across the Potomac River from Washington. A large steel still was set up in the center of the big building. Two bags of corn cobs were dumped into the cylinder; then the top was screwed on and the steam turned in. After digesting for a couple of hours the furfural was distilled in a stream of steam, and the water and furfural condensed together by cooling. This mixture is afterwards separated by redistillation.

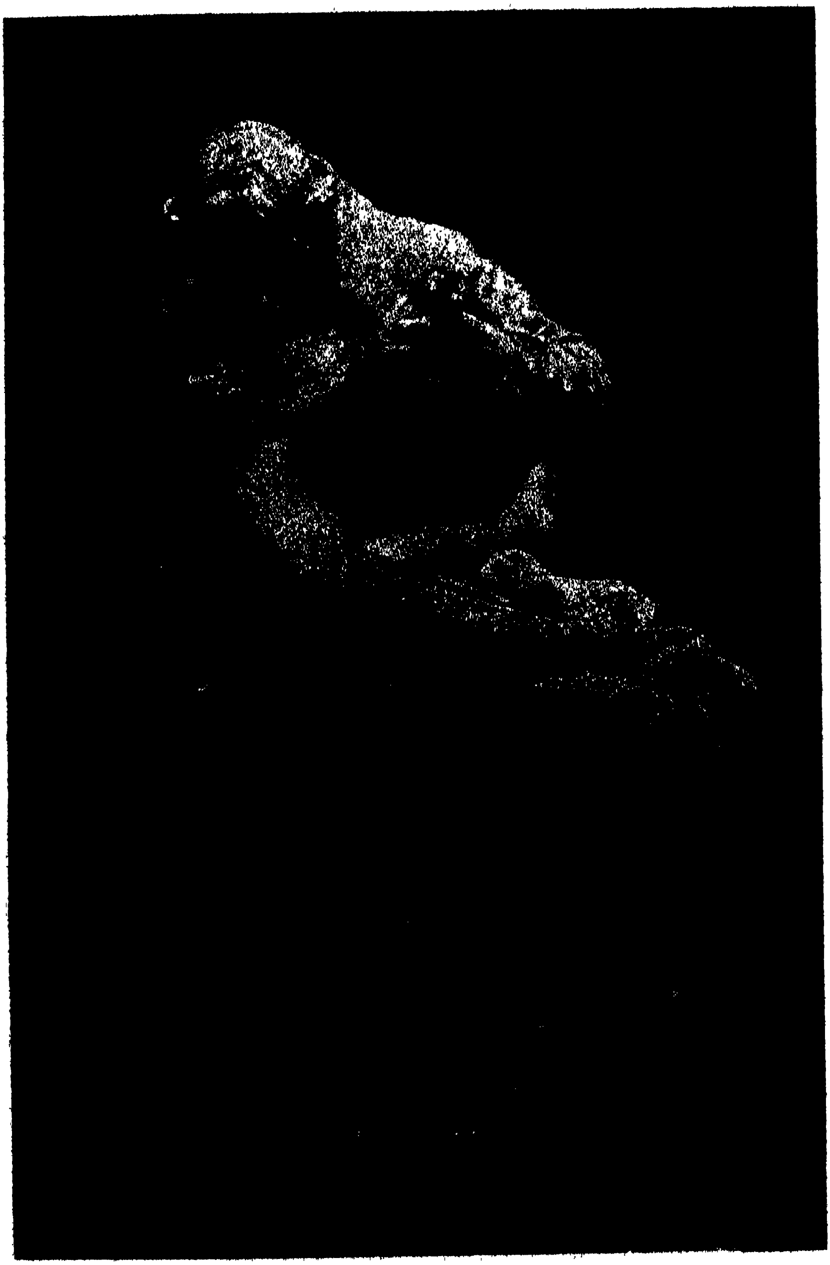
Furfural is a liquid, clear and colorless as water when fresh and pure, but turning brown when exposed to light and air. It takes fire easily and burns with a bright flame. It has a characteristic odor, but not strong or unpleasant. It is what the chemists call a "ring compound," for its molecule is composed of four carbon and one hydrogen atoms, connected in a ring with an extra atom of carbon and another of oxygen and four hydrogen atoms attached outside.

But we are all more interested in what furfural can do than what it is. This, however, remains to be found out. The first thing that we think of is using it as a motor fuel, since a shortage of gasoline is impending. Furfural can run a car, but does not seem to be suited to the ordinary type of motor and anyhow it is still twice as high as gasoline and therefore out of reach.

Furfural is poisonous to insects and germs. Perhaps it could find employment here. It will dissolve paint and varnish, also fats and airplane dope.

More promising yet are its compounds. Furfural will combine with various coal tar products such as aniline and carbolic acid. With aniline and the like, it makes dyes of a variety of colors, but those so far made are fugitive.

With carbolic acid, furfural combines to form resins very much like bakelite, which is made from carbolic acid and formalin. These may be used in liquid form for varnishes or in solid form as insulation in electrical apparatus. We may expect furfural some day to appear in dis-



EDWARD JENNER

The centenary of whose death was celebrated on January 23. The illustration is from a bronze statue by Monteverde in the Museum of the Royal Society, London.

EDWARD JENNER
Showing the vaccination of his first patient in 1796. From the painting by Mélingue.

guise as amber beads or tortoise shell combs or ivory billiard balls or horn buttons. Phonograph records may be made from it, also plates for printing from instead of type. They are light, hard and tough.

In short, furfural is now in the position of a high-school graduate whom the principal claps on the shoulder and says: "You are a bright, versatile fellow. There is a great future before you." But when the boy asks, "Where?", he gets no answer.

This newcomer is knocking at the factory door with no credentials but a letter of introduction from the chemist which does not go far in the factory. The busy manufacturer turns to him long enough to ask: "Can you do anything better than those I've got or do it cheaper?" The applicant can only answer: "I don't know, sir. I think so, but I've never had a chance to show what I can do yet. Won't you give me a try-out?"

I can't give the answer of the

business man because I don't know what it is.

THE SILKWORM'S RIVAL

MAN has entered into active competition with the silkworm and, although the worm has the advantage of several million generations of previous practice in the art of silk making, man is rapidly catching up. The output of artificial silk has increased fivefold during the last twenty years, while the output of natural silk has only gained fifty per cent. More than a third of what seems silk to the eye comes from the factory instead of the cocoon. Some forty million foreign feet are now encased in synthetic silk stockings made in America.

Artificial silk is not silk and should never be sold as such. But if it is, it is not so much because the salesman desires to deceive, as it is because the public is unwilling to credit the chemist with the creation of something new or to believe that he can make anything so good as is made by a worm. Of late this unnatural prejudice in favor of nature is being overcome and the new synthetic fibers are being marketed by their manufacturers as they should be under synthetic names. Some of the trade names are viscose, lustron, fibersilk, lustre-fibre, Givet silk, Soie de Paris, Glanzstoff, artiseta, lustracellose. There are a lot of others, but I omit to mention them because I can't remember them.

There are four different modes of manufacture but the raw material is essentially the same, cellulose. This is the substance of wood, paper and cotton, so it is cheap and abundant enough, but the difficulty is to dissolve it so it can be squirted out of the tiny holes in the spinnerette to form the fibers. Water will not dissolve paper pulp, of course, nor will any ordinary solvent except strong acids and alkalies.

The first person to solve the problem was a Frenchman, Count de Chardonnet, who in 1884 deposited with the French Academy of Sciences a sealed document. Three years later this was opened and found to contain a method of making artificial fiber by treating cellulose with nitric acid. The resulting compound, which is a mild form of gun-cotton, can be dissolved in alcohol and ether, like the common collodion that we use to cover our skinned knuckles. But the nitric had to be thoroughly eliminated from the yarn, otherwise it was too inflammable.

Another process, invented by the French and worked by the German, got the cellulose into fluid form by dissolving it in a solution of copper and ammonium salts.

In the making of viscose a third method is employed. Wood pulp, such as is used in paper making, is treated with strong soda lye and then with carbon disulfide. This brings the cellulose into solution as an orange liquid. This is forced through minute holes in a platinum nozzle into dilute acid, which hardens each fine stream into solid fiber and the sulfide is then removed.

During the war another form of soluble cellulose found extensive employment as "scac" or dope for airplane wings. This is the acetate, made by dissolving cotton or wood pulp in the concentrated acid of vinegar, acetic. Lustron is made by this process.

These various kinds of artificial fibers differ from one another and all of them differ from natural silk. And in this difference lies their value. For fabrics can be woven out of natural and artificial silk and with cotton or wool in any desired combination. The fabric at first may look white and uniform, but if it is dipped in baths of various dyes each thread will attach a particular tint and a complicated design brought out in color.

The artificial fibers and the coal-tar dyes make a brilliant combination and through the aid of this alliance our world has become more

colorful and cheerful. Sweaters and hose, neckties and underwear, have blossomed out in varied hue like the flowers that bloom in the spring. The knitting machine has taken a new spurt and is now running a race with the loom. Our ladies may now wear synthetic lace that is shadowed by no thought of toilsome fingers and bent shoulders. They may wear synthetic furs without the sacrifice of wild life.

Man is no longer dependent upon what he can pick up in the plant or animal kingdoms, for the new fiber can be made in any form desired, flat or round, smooth or rough, thick or thin, and of any length. A single filament may be run out thousands of yards without knot or break.

The man-made fiber is not so strong as the worm-made silk, especially when wet, but this has not interfered with its popularity so much as the fact that it is lacking in scroop. The scroop, as the sound of the word suggests, is the audible evidence of the presence of silk. What is the use of owning a silk petticoat if nobody can hear it as you pass by? But science is overcoming even this obstacle.

HOW WORDS LOSE REPUTATION

LANGUAGE is a circulating medium, as money is, and words, like coins, are apt to lose their value in the course of time. A decline in the exchange rating of a word may be due either to inflation, that is, too promiscuous application, or to a growing popular suspicion of the soundness of its backing.

The Seven Wise Men of early Greece were called "sophists" as an honorific appellation. But later, a "sophist" came to mean a man who pretended to know more than he did or, worse, who sold his wisdom to the highest bidder for the basest of purposes, that of making a wrong cause seem right.

Pythagoras repudiated the title of sophist, or wise man, because, as he said, "none is wise save God." So he devised and assumed the more modest sounding term of "philosopher," a lover of wisdom. But this term has narrowed, if not degenerated. Philosophy, once the sum total of human knowledge, has come, in common parlance, to be confined to speculative metaphysics. When Plato said that states should be ruled by philosophers he did not mean by professors of metaphysics.

This degenerative process has gone so far that we have no word in good repute and common usage to apply to a group of competent and learned men. The word "scholars" would once have served, but this has fallen from its high estate and come to mean "pupils," that is, those who are being schooled, instead of those who have been schooled. To call a man a "sage" calls up in the average mind the picture of something grey and pedantic, if not green and aromatic. The word "scientist" has become so narrowed and lowered and misapplied that men of science hesitate to use it longer. The titles of "professor" and "expert" are also distinctly losing caste.

To call a man a "fellow" is not safe now-a-days outside of the campus of a university.

It is hard to arrest a word when it is on the down grade and almost impossible for a word to regain a reputation once lost. It seems that some sort of gravitational force prevails in linguistics. The dictionary is crowded with words that once moved in the highest circles, but now are outcast and marked "obs." or "vul."

The man who knows comes in the course of time to be considered a "knowing man," with the suspicion of knowing too much for his neighbors. The "kenning man" becomes the "cunning man." A master of arts gets the reputation of being "artful." A craftsman is regarded as "crafty." A politician has come to mean—well, a politician.

Four hundred years ago the word

NICOLAUS COPERNICUS

The four hundred and fiftieth anniversary of whose birth occurred on February 19. The illustration is from a painting by Brausewetter.

"virago" meant a heroic woman and was esteemed a fitting name to apply to Eve, the mother of all living. Now-a-days no one would dare call a woman a virago to her face if she were one. "Hussy" has degenerated in a hundred years from a thrifty "housewife" to quite the opposite.

In Australian newspapers to-day you may see a lonely bachelor advertising for "a homely wife," not because he has an aversion to feminine beauty, but because he desires domesticity.

A "wretch" was not at all wretched on the start. Othello calls his beloved Desdemona "Excellent wretch." A modern maiden would not feel complimented by such a term of endearment.

A "prude" was merely a prudent person.

A "villain" and a "boor" once meant simply a countryman, not necessarily wicked or even rude. A "knave" was a simple servant. A "varlet" was a candidate for knighthood. A "miscreant" meant one who differed from you in theology.

In 1548 it was proper to express the pious wish "that his son, Prince Edward, that good imp, may long reign over you." How is it that "imp" has since come to mean a little devil?

So, as we see, words generally degenerate as they grow old. That does not matter much, for we can always make new words so long as the alphabet holds out. I am not concerned over the loss of a name, but I am with the loss of the type that the name once signified. If an ancient and honorable title falls into disrepute it is not altogether without reason. It means that some at least of those who bore it have not lived up to its true meaning.

It would be a profitable exercise to consider such cases as occur to us of words that we see are gradually becoming lowered or limited and try to discover the cause of their decline and how it may be prevented.

A DANGEROUS MENTAL MALADY

The progress of mankind has been in all ages greatly retarded and at times altogether prevented by a curious sort of disease of the mind technically known as neophobia. In a case of hydrophobia the mere sight of water is said to arouse disgust, fear and even furious anger. In a case of neophobia the symptoms are similar but the cause is different. The neophobic patient shows marked aversion and resentment at the sight of anything new. The disease is very prevalent and there are no drugs known that will cure it, except poisons. We all seem to carry about the germs of it, for any of us is liable to manifest mild symptoms, and in certain countries and certain centuries it has been epidemic.

I came across a striking case of neophobia the other day in a letter written in March, 1825, by Thomas Creevey, when a bill for the construction of the first railroad line was introduced into parliament. This is what he felt about it:

> I have come to the conclusion that our Ferguson is *insane*. He quite foamed at the mouth with rage in our Railway Committee in support of this infernal nuisance—the locomotive Monster, carrying *eighty tons* of goods, and navigated by a tail of smoke and sulphur coming thro' every man's grounds between Manchester and Liverpool. . . . Well—this devil of a railway is strangled at last. To-day we had a clear majority in committee in our favour and the promoters of the Bill withdrew it and took their leave of us.

This reminds us of the speech of Sir Charles Napier in the House of Commons when it was proposed to introduce steam power into the navy:

> Mr. Speaker, when we enter Her Majesty's naval service and face the chances of war, we go prepared to be hacked in pieces, to be riddled by bullets or to be blown to bits by shot and shell; but, Mr. Speaker, we do not go prepared to be boiled alive.

The same temper was manifested by the Roman sage, Seneca, when he denounced the waterworks and heating systems that were being intro-

duced into Rome houses and the buildings of several stories that were beginning to appear on the Palatine Hill. "These towering tenements," he said, "are dangerous to the persons who dwell in them." Dangerous to their morals, he meant, of course; not that he was afraid of the buildings falling down. "Believe me," he adds, "that was a happy age before the days of architects, before the days of builders." "A thatched roof once covered free men; under marble and gold dwells slavery." If he had seen a modern thirty-story skyscraper the Latin language would not have been sufficient to express his emotions.

When it was proposed to use coal gas for lighting, Sir Walter Scott called it "a pestilential innovation" and Napoleon considered it "une grande folie" and Byron satirized it in his verse among the passing fads.

When bathtubs were first installed in the United States in the forties the papers attacked them as extravagant and undemocratic and the doctors denounced them as dangerous to health. As usual, government was called upon to restrict or suppress the novelty by special taxes and licenses. In 1843 Virginia put a tax of $30 a year on bathtubs and in 1845 a Boston municipal ordinance made bathing unlawful except on medical advice.

The first printed books had to be sold as manuscripts because of the prejudice against printing. The learned men of Italy sneered at the invention as a barbarous German innovation.

The first shipload of saltpeter sent to England from Chile could not find a buyer and had to be thrown into the sea.

The first bananas shipped to London could not be sold at any price or even given away in the slums, but were left to rot because nobody would eat them.

When they were first introduced into England potatoes were denounced as injurious to society and tomatoes as injurious to morality.

All this is history now and so merely amusing. But it may make us stop a minute to consider if we are to-day opposing some similar innovation from unconscious neophobia.

SCIENTIFIC ITEMS

We record with regret the death of John Trowbridge, Rumford professor emeritus of physics at Harvard University; of Albert Stowell Flint, astronomer emeritus of the Washburn Observatory, University of Wisconsin; of John Waddell, associate professor of chemistry and librarian of the science department at Queen's University, Kingston; of Fritz Cohn, director of the Berlin Rechen-Institut and professor of theoretical astronomy in the university, and of Johannes Diderik Van der Waals, of the University of Amsterdam, who received the Nobel prize for physics in 1910.

Dr. Edouard Benjamin Baillaud, director of the Paris Observatory, has been given the Bruce gold medal, awarded by the Astronomical Society of the Pacific.—The Nichols medal of the American Chemical Society has been awarded to Thomas Midgley, Jr., head of the fuel section of the General Motors Research Corporation laboratories at Dayton, Ohio.—Dr. John Dow Fisher Gilchrist, professor of zoology in the South African College at Capetown, has been elected president of the South African Association for the Advancement of Science for the meeting to be held at Bloemfontein in July.

Mr. Arthur H. Fleming, of Pasadena, president of the board of trustees of the California Institute of Technology and its chief financial supporter, has recently given to the institute his fortune of $4,200,000 as a permanent endowment fund.—Sir Alfred Yarrow, an engineer and shipbuilder of Glasgow, has given £100,000 to the Royal Society for the promotion of scientific research.

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COLD WAVES, NORTHERS AND BLIZZARDS IN THE UNITED STATES

By Professor ROBERT DE C. WARD

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Beginnings of an Understanding of Cold Waves

"It will be readily seen that on the approach of a great storm from the lower latitudes by the usual routes, while revolving from right to left, its first effect will be to bring in the warm and humid air of a more southern region; and when the axis of the gale has passed, the contrary result necessarily follows. . . . Indeed, this rising of the thermometer during the access of winter storms, and its great depression as they pass off in their northeasterly courses, might in itself afford us good proof of the storm's rotation, were more direct evidence wanting." Thus, in 1846, wrote William C. Redfield, one of the brilliant group of American meteorologists of the middle and latter portion of the nineteenth century.[1]

The real beginning of an understanding of American cold waves is found in this statement. In July, 1861, in a remarkable letter written by Professor Joseph Henry, then secretary of the Smithsonian Institution, to General Sabine, the first use of the term *wave* occurs in connection with the advance of winter cold spells across the eastern United States. "We find that not only do the storms of wind and rain come to us (at Washington) from the west, and enter our territory from the north (near the Rocky Mountains, in British possessions, about 110° west), but also the cold and warm periods. The early and late portions traverse the country in the form of a long wave extending from north to south,

[1] William C. Redfield: "On three several hurricanes of the Atlantic and their relations to the northers of Mexico and Central America, with notices of other storms," 8vo., New Haven, Connecticut, 1846, pp. 102, 104. The papers collected in this publication first appeared in the *American Journal of Science*.

and moving eastward. When this wave arrives at a given meridian during the night, a killing frost is experienced along a band of country extending north and south, it may be in some cases more than a thousand miles, while in an east and west direction it is not more than fifty or a hundred miles."[2] "From the observations made at this institution," Professor Henry further said, "the waves, as it were, of cold which reduce the temperature of the United States frequently begin several days earlier at the extreme west."[3] Further, speaking of a forthcoming volume of meteorological observations to be published by the institution, the secretary said: "This volume will also contain special thermometric observations at stations distributed over the area extending from the Arctic regions to the northern states of South America; and from the Pacific to the Atlantic coast, for the purpose of showing the progress of cold periods across the continent, from the Rocky Mountains to Bermuda."[4]

Thus, a decade before the publication of the first regular daily weather maps for the United States, the eastward progression of *waves* of cold from the Rocky Mountains to the Atlantic coast was clearly recognized. Indeed, as far back as 1793 emphasis was laid on the greater frequency and severity of winter cold spells in New England than in corresponding latitudes in Europe, although the low temperature was wrongly attributed to the descent of the northwest winds from the Appalachian Mountains, and there was, naturally, no recognition of the cyclonic control over these winds.[5] The importance of cold waves in relation to agriculture, transpor-

2 The present writer has been unable to find either the original letter from Professor Henry to General Sabine, or the first printing of it. Through the courtesy of Dr. Charles D. Walcott, the present secretary of the Smithsonian Institution, a search was made and no record was found of the letter, which may have been destroyed with practically all the other records of the institution in the fire of 1865. The meteorological material at the Smithsonian Institution was later turned over to the Signal Office of the United States Army, after the establishment of the government meteorological service in 1870. Professor C. F. Talman, librarian of the United States Weather Bureau, has very kindly made a search through the files of the Bureau, but without success. The quotation here given is taken from Fitz Roy's "Weather Book" (p. 137), where Professor Talman informed the writer that the letter was printed. Curiously enough, the letter is not found in the two volumes of Henry's scientific writings, published in 1886 by the Smithsonian Institution.

3 *Ann. Rept. Smithson. Instn. for 1861*, Washington, D. C., 1862, p. 20.

4 *Ibid*, p. 37.

5 Samuel Hale: "Conjectures of the natural causes of the northwest winds being colder and more frequent in the winter in New England than in the same degrees of latitude in Europe," *Mem. Amer. Acad. Arts and Sciences*, Vol. 2, 1793, pp. 61-63.

tation and other interests has naturally led to a considerable study of these phenomena, chiefly from the point of view of the forecaster.[6]

Definition of a Cold Wave

Not every considerable and sudden fall of temperature in the United States is a cold wave. For forecasting purposes it is necessary to define certain limits, both of time and temperature-fall. A cold wave, according to the official definition adopted by the U. S. Weather Bureau, is a drop of a certain number of degrees of temperature within 24 hours, with a minimum falling below a fixed temperature. The amount of drop, and also the minimum, are different for different sections and for different seasons, the definite values in each case having been arbitrarily fixed with a view to securing the best possible protection for agricultural and commercial interests.

Figure I shows the required temperature falls (within 24 hours) and the minimum temperatures necessary to give a cold wave,

[6] Lists of notable cold waves may be found in Lorin Blodget, "Climatology of the United States," 1857; A. W. Greely, "American Weather," 1888 (pp. 216-222); and E. B. Garriott, "Cold waves and frost in the United States," *United States Department of Agriculture Weather Bureau Bulletin P. 4°*, Washington, D. C., 1906, pp. 22, chs. 328. The last named publication "notes briefly the general distribution of the colder areas of the northern hemisphere, refers to general conditions that are associated with cold waves, and presents a chronological account of historical cold periods in the United States. It then summarizes and classifies the more important cold waves and frosts that occurred from 1888 to 1902 inclusive, and presents 328 charts that exhibit the meteorological conditions that attended the principal cold waves of that period." Reference may also be made to Alfred J. Henry, "Climatology of the United States," *United States Department of Agriculture, Weather Bureau, Bulletin Q 4°*, Washington, D. C., 1906, and, for a recent discussion of cold wave forecasts, to "Weather forecasting in the United States," by a board composed of Alfred J. Henry, chairman, Edward H. Bowie, Henry J. Cox and Harry C. Frankenfield, *United States Weather Bureau, No. 583*, 8 vo., Washington, D. C., 1916. Professor H. J. Cox contributes the general discussion of cold waves (chap. VI, pp. 143-176), which is illustrated by weather maps typical of various cold wave conditions. Fig. 66, p. 148, shows the number of cold waves which occurred between 1904 and 1914 inclusive. There are also shorter papers by the district forecasters on the cold waves of the different sections. The *Monthly Weather Review* regularly contains discussions of cold waves as they occur, often illustrated by special weather maps. Several pamphlets issued by the United States Department of Agriculture have discussed the subject of frost and of cold waves and have indicated methods of protection against frost and cold. See, *e.g.*, E. B. Garriott, "Notes on frost," *United States Department of Agriculture, Farmers' Bulletin 104*, 8 vo., Washington, D. C., 1899; revised by A. G. McAdie, August, 1911. An early publication on cold waves is T. M. Woodruff, "Cold waves and their progress," United States Signal Service Notes No. 23.

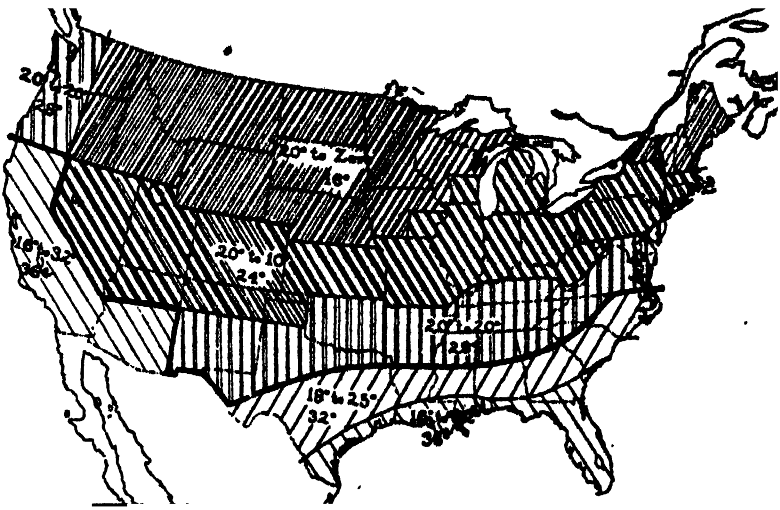

FIG. I. COLD WAVE CHART FOR THE UNITED STATES.

according to the official definition of the U. S. Weather Bureau. The upper figures are for winter; the lower for the other months. Above the heavy line the winter months include December, January, February and March; below it, December, January and February. It is to be observed that the cold wave is simply a certain condition of temperature, and the definition has nothing whatever to do with the wind. In the popular mind, however, the wind which brings the cold and the cold itself are always thought of as constituting the cold wave. The amounts of fall of temperature are the same in all seasons for each individual district, but the limiting minima vary, being lower in winter and higher during the rest of the year. These minima, furthermore, are not as far below the normal in the north as in the south. Along the Gulf and southern Pacific coast, for example, where crops are growing the year round, temperatures below freezing are dangerous at any time. The limiting temperatures being but slightly below the normal in the north, and much below normal in the south, the number of cold waves recorded in the north is naturally much greater than that recorded in the south. The cyclonic conditions favorable for cold waves are also more frequent along and near the northern border.

General Description of a Cold Wave

For severity, suddenness and frequency of occurrence the cold waves of the eastern United States are unique. They are typically American phenomena. As first pointed out by Redfield, they are a characteristic feature of the rear of winter cyclonic storms, and

follow warmer weather, accompanied by winter rains or snow, in front of the low pressure center. Following the passage of the centre, especially when there is a well-developed high pressure area in the northwest and the wind-shift line is well developed, the cold wave is heralded by a sudden shift of the wind to the west and northwest—a piercing blast, sweeping down from the cold continental interior of western Canada, reducing the temperature 20°, 30°, 40°, or even more, within 24 hours. The drop in temperature often begins before the rain or snow has ceased falling. If it is still raining when the westerly wind begins to blow, the rain quickly turns to sleet, and an icy covering forms on all objects outdoors. If it has been snowing, the snow soon becomes hard and dry. The wheels of passing vehicles, the runners of sleighs and the footsteps of pedestrians "sing" with a metallic sound. The ice on rivers and lakes tightens its grasp, and cracks and "booms" with a reverberating sound. The collars of great coats are turned up; hands are put into muffs or pockets; people walk more briskly; every preparation is made for a spell of hard cold weather.

The northwest wind blows with considerable velocity for a day or more, accompanied by clear skies and bright sunshine, and then gradually diminishes. While the cold is more keenly felt during the blowing of the strong wind, the actual minimum temperatures are recorded on the two or three, or perhaps more, calm, clear nights which follow, in the central portion of the anticyclone. Under these conditions, nocturnal radiation fogs are common. The cold wave proper is, therefore, not at the center of the high, but on its southeastern margin and to the southwest of the preceding low, in the area occupied by the northerly and northwesterly winds.

From their northwestern origin the areas of cold, usually more or less elliptical in shape with the longer axis extending southwest-northeast and covering hundreds of thousands of square miles in extreme cases, progress in a general easterly or southeasterly direction towards the Atlantic or Gulf coasts, but with much diminished intensity, as they enter warmer latitudes and increase their distance from their frigid northern source. In Figure II the "cold wave axis" shows the middle frontage of cold waves as they come down from the northwest in the winter months, as plotted by Professor F. H. Bigelow.[7] The axes of certain characteristic types of individual cold waves, greatly generalized, are indicated (fol-

[7] F. H. Bigelow: "Storms, storm tracks and weather forecasting," *United States Weather Bureau, Bulletin 20*, 8 vo., Washington, D. C., 1897; reproduced in the *Atlas of Meteorology*, Pl. 28.

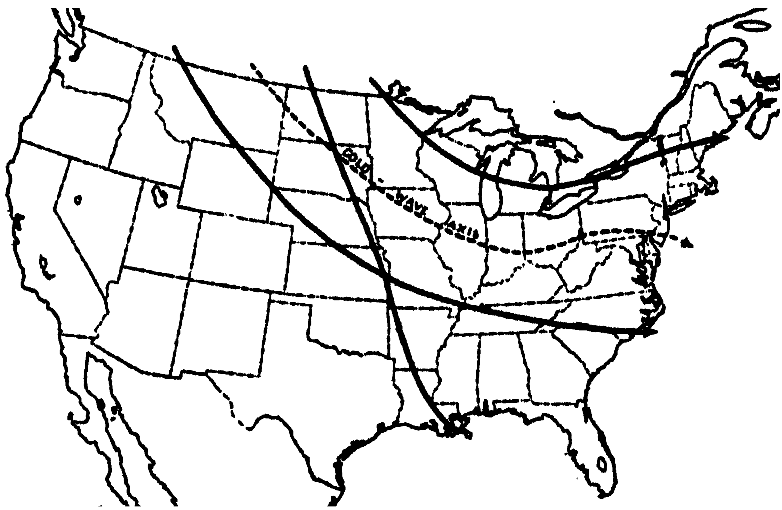

FIG. II. COLD WAVE AXIS AND GENERALIZED PATHS OF COLD WAVES ACROSS THE EASTERN UNITED STATES.

lowing J. P. Finley) by the broad lines, the direction of progression being shown by the arrow-head. The rate of advance is determined by the rate of progression of the controlling cyclonic and anticyclonic pressure systems. A cold wave may easily sweep over the country from the northern plains to Texas or to the Atlantic coast in two or three days. As it advances, it gradually becomes less severe, especially (1) if the ground is not snow-covered; (2) in the early spring, and (3) during the daytime, when the increasing warmth of the sun is able to warm the earth's surface more effectively. The lower air may then become more or less unstable. Convectional overturnings, flurries and eddies occur. The wind blows with a somewhat higher velocity during the day. If, on the other hand, the northwest wind blows at night over a snow-covered surface, the temperature of the lower stratum may be somewhat reduced as the cold wave sweeps forward on its course.

It is fairly safe to expect, on the average, three or four severe cold waves every winter in the eastern United States, but such intense cold spells do not, as a rule, last longer than two or three days except over the northern plains, and are naturally more frequent in the north than in the south. After about the middle of February the duration of these "cold snaps," as they are often popularly termed, usually lessens perceptibly. Conditions similar to those which produce the cold waves of winter, but far less marked, prevail also in summer. The clearing northwest winds in the rear of a passing summer cyclonic storm, or after a well-developed wind-shift line thunderstorm, are pleasantly cool, dry

and refreshing, following, as they do, a spell of muggy and oppressive heat which has accompanied the southerly winds on the front of the low. These summer "cool waves" therefore give welcome relief during the hot months, and are an important factor in making the climate of that season more agreeable and more healthful.

Factors Favorable to Cold Waves

Several factors combine to produce the severe cold spells of the eastern United States. While the cold "wave" itself is directly due to the temporary pressure distribution, as will shortly be explained, the initial source of the cold is to be sought in the larger climatic conditions of the North American continent. During the long winter nights, under the prevailingly clear anticyclonic skies and in the dry air of the northern treeless continental interior, active radiation from the lower atmosphere, both to ground and sky, reduces the temperature to very low readings. These fundamental conditions doubtless supply most of the cold, which is then imported to lower latitudes.[8] The permanent winter high pressure conditions over the northern portions of North America accelerate this flow of cold air, which is most active when a well-developed anticyclone follows the retreating cyclone. In addition, the original cold is reinforced and more or less effectively maintained by the active radiation which takes place in the dry clear air of the western quadrants of the cyclone and of the following anticyclone, as these move eastward across or along the northern border of the United States. This local reduction of temperature during the advance of the cold wave is especially effective when the ground is covered with snow. The minimum temperatures, as has just been indicated, are not recorded during the active blowing of the northwest wind, but on the clear, calm anticyclonic nights which follow.

Another factor of essential importance in the production of American cold waves is the frequency, intensity and rapid progression of the winter storms. A further condition which makes the fall of temperature so marked is the presence of the warm ocean and Gulf waters to the south. Across these blow the warm southerly winds in advance of the low pressure areas, importing the high temperatures with which the succeeding cold is in such sharp contrast. There is, further, a series of topographic controls peculiar to North America. The Rocky Mountains constitute an effective barrier to the west. Hence cyclonic storms moving across

[8] See, *e.g.*, a discussion by Sir F. Stupart and the late Professor Cleveland Abbe on the origin of American cold waves in *Month. Wea. Rev.*, vol. 32, 1904, p. 113.

the Great Plains and then eastward can not readily supply their rear indraft from the west, and in place of that draw heavily on the reserves of colder air to the north. Further, this dry, cold, dense air finds itself moving with the general slope of the country down the Mississippi Valley towards the Gulf of Mexico and eastward towards the Atlantic, easily underrunning the warmer, lighter air on the front of the storm along the wind-shift line. The absence of any transverse mountain ranges across the great central lowlands leaves an unobstructed path for the cold waves to invade the whole tier of states bordering on the Gulf of Mexico. These temporary incursions of cold are one of the most serious climatic handicaps of the southern states from an agricultural standpoint. The long stretch of the Appalachian Mountains, paralleling the Atlantic coast, is not sufficiently high or massive to constitute an effective barrier against the advance of cold waves from the interior, although it does, not infrequently, furnish some protection to the southern Atlantic coast states when severe cold waves prevail to the west of the mountains.

Some Economic Aspects of Cold Waves

A climatic phenomenon marked and far-reaching in its economic effects is the cold wave. Many and varied are the ways in which it affects man and his multitudinous activities and interests, as the Weather Bureau has often pointed out. When a cold wave is on the way, heating plants, whether steam, electric or natural gas, are prepared for an increased demand, and individual heating systems and furnaces are run at full blast. Greenhouses are closed and kept at a higher temperature. Fire-plugs and exposed water pipes are protected. Gasoline engines out of doors are drained. The water in automobile radiators is mixed with alcohol or some other non-freezing liquid. Railway companies arrange for more heat in their passenger cars; accelerate the movement of perishable goods, and heat the cars containing them, or run these cars under cover for protection. The announcement of a cold wave is usually followed by hastened shipments of cold storage eggs from the western supply districts to the eastern markets, in anticipation of a rise in prices. On the other hand many goods are not shipped until the cold spell is over. Advertisements call attention to cold weather goods. Coal and wood dealers prepare for sudden demands for fuel. The dredging of sand and gravel ceases. Iron ore ready for shipment is protected so that it shall not freeze. Ice companies watch the increasing thickness of the ice forming in their supply reservoirs and decide whether to cut at once, or, if the cold is to be severe and prolonged, to wait for thicker ice.

Philanthropic organizations of all kinds prepare for sudden demands for fuel, food and clothing on the part of the poor. In districts where outdoor crops are exposed to the cold, and to frosts accompanying or closely following the advent of a cold wave, as in the citrus fruit orchards of southern California or the truck-gardens of the Gulf and southern Atlantic coasts, immediate preparations are made for adequate protection by means of thoroughly organized methods. In certain cases the crop may be saved from damage by being gathered in advance of the arrival of the damaging cold. In these, and in countless other ways, cold waves play a distinct part in the lives of many millions of people in the United States.

Instrumental Records of Cold Waves

A more vivid picture of the general characteristics of these sudden cold spells, which, of course, do not always meet the official definition of a cold wave, will be secured by a glance at the thermograph and barograph records obtained at a New England station. The temperature and pressure curves are supplemented by ob-

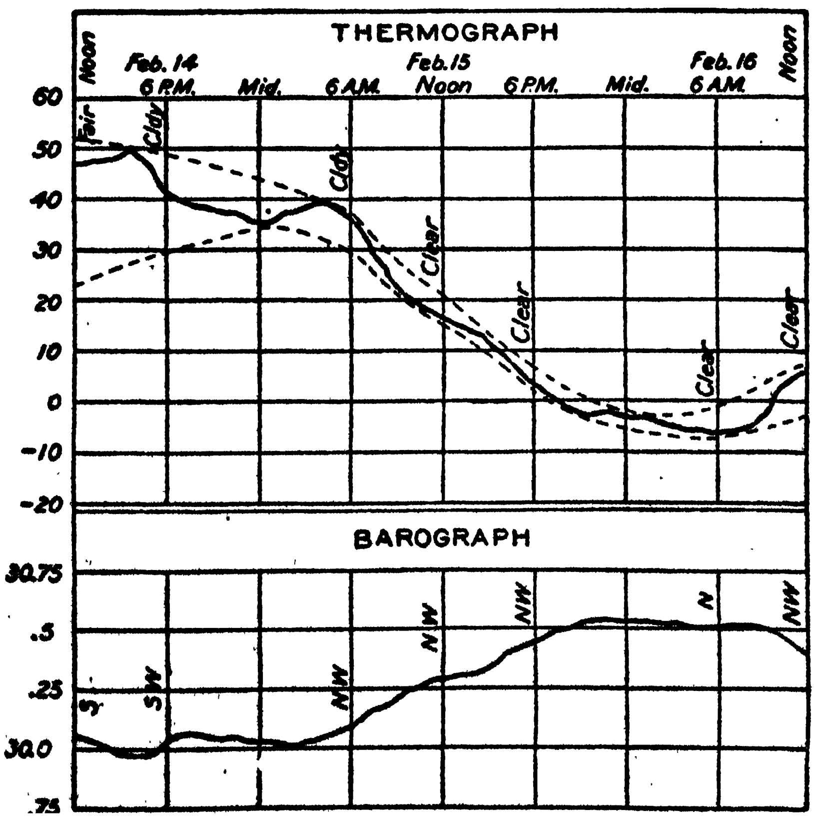

FIG. 111. FEBRUARY COLD WAVE (February 14-16).

servations of the state of the sky and of wind direction. The conditions here represented are more or less typical for the whole area east of the Rocky Mountains, with modifications resulting from latitude and other controls. Figure III illustrates a February cold wave. A maximum temperature of 50°F. is reached under the warm, damp, muggy southerly winds of a winter cyclone passing by on the north. With a shift of wind into the northwest, as the wind-shift line passes the station, a rapid fall of temperature takes place from the early morning of one day (February 15), through noon, with practically no trace of diurnal warming although the sky is clear, to the early morning of the next day (February 16). The minimum (—5°) comes under the clear skies and light winds at the crest of the high. The cyclonic control of temperature is strikingly brought out in the drop of the temperature belt (enclosed by the broken lines) from one side of the diagram to the other. The fall in temperature was over 50° in 36 hours, and during all that time a strong biting northwest wind was blowing. Sudden temperature changes of this sort make it hard for persons who are not in robust health to endure the winters in the eastern United States. Figure IV is a good example of typical winter temperature changes under cyclonic and anticyclonic controls. A marked maximum of about 60° comes at the time of lowest pressure, under the control of the warm southwesterly winds and cloudy weather in association with the front of a winter cyclone passing by on the north (*cf.* Fig III, February 14). The two minima come at the crest of the two high pressure areas. On January 1 the minimum is at the initial midnight; the maximum is at the final midnight; the "diurnal range" is wholly cyclonic. On January

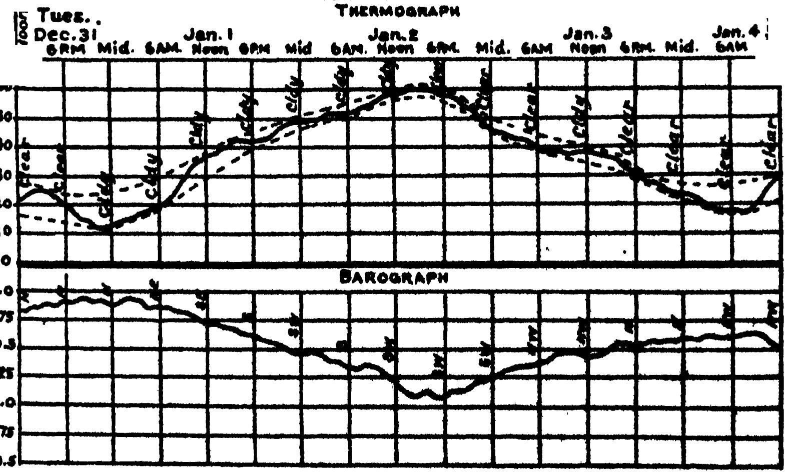

FIG. IV. TYPICAL WINTER TEMPERATURE CHANGES (December 31-January 4)

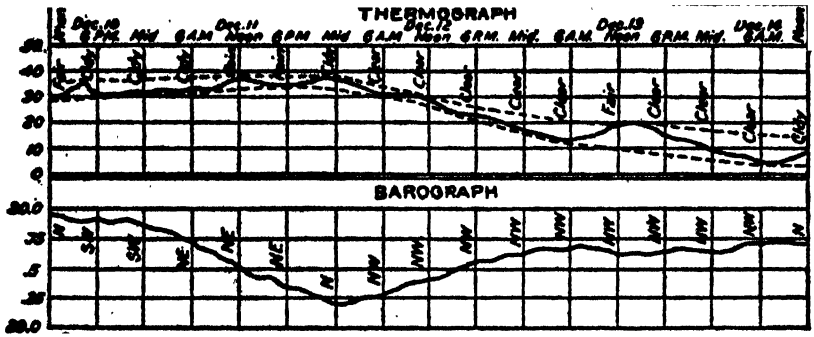

FIG. V. MODERATE DECEMBER COOL WAVE (December 10-14).

3 the maximum is at the initial midnight and the minimum at the final midnight. This is exactly the opposite condition, but the diurnal range of temperature is again wholly cyclonic. On January 1 and 2 the normal diurnal curve, with the maximum in the early afternoon and the minimum in the early morning, has completely disappeared under the more powerful cyclonic control.

In Figure V the rise of temperature in front of the approaching cyclone was only moderate (maximum under 40°), because of the blowing of rainy northeast winds (December 11) from the ocean. The fall of temperature under the northwest winds and

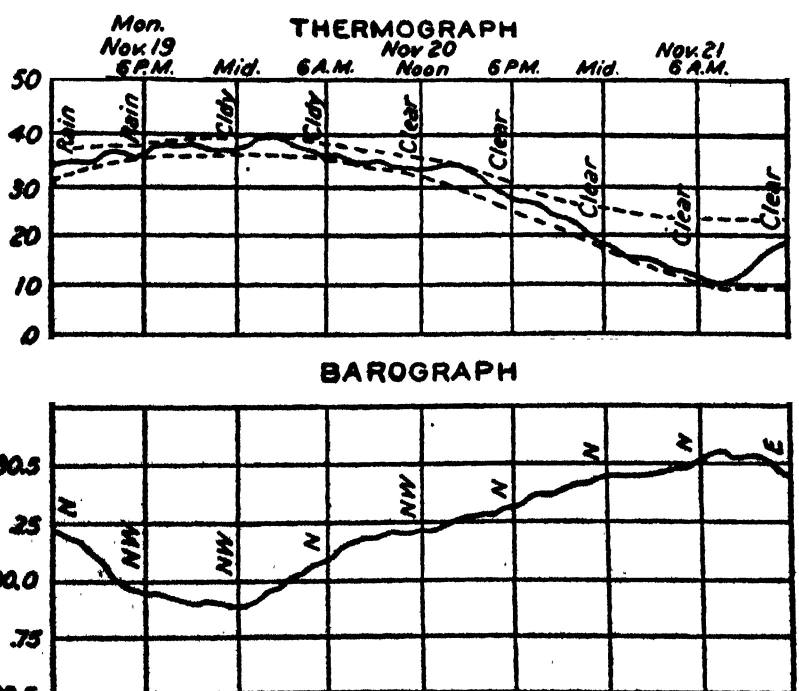

FIG. VI. NOVEMBER COLD SPELL (November 19-21).

clear skies of the succeeding anticyclone brought the thermometer down from between 35° and 40° to 5°, but rather slowly, as the pressure gradients were not steep, and the northwest winds of moderate velocity. The cool wave carried the temperature belt down, the downward slope being only slightly interrupted by a weak diurnal maximum under solar control on the afternoon of December 13.

During the autumn, the cyclonic control is less marked and the cold less severe. Figure VI illustrates a November cold spell. After a nocturnal maximum (November 19-20) of 40°, a fall in temperature beginning shortly after midnight continues over noon (November 20) and until early morning of the following day (November 21). Such a fall of temperature over noon is one of the characteristic signs of approaching winter. It shows the weakening solar and the increasing cyclonic control of the weather. The temperature belt is very narrow, showing slight diurnal ranges of temperature under the rain and the cloudy skies of November 19, and widens under the clear skies and light winds of the anticyclone (November 21). The minimum temperature (November 21) comes under the clear sky of the anticyclonic night, with very light northerly winds.

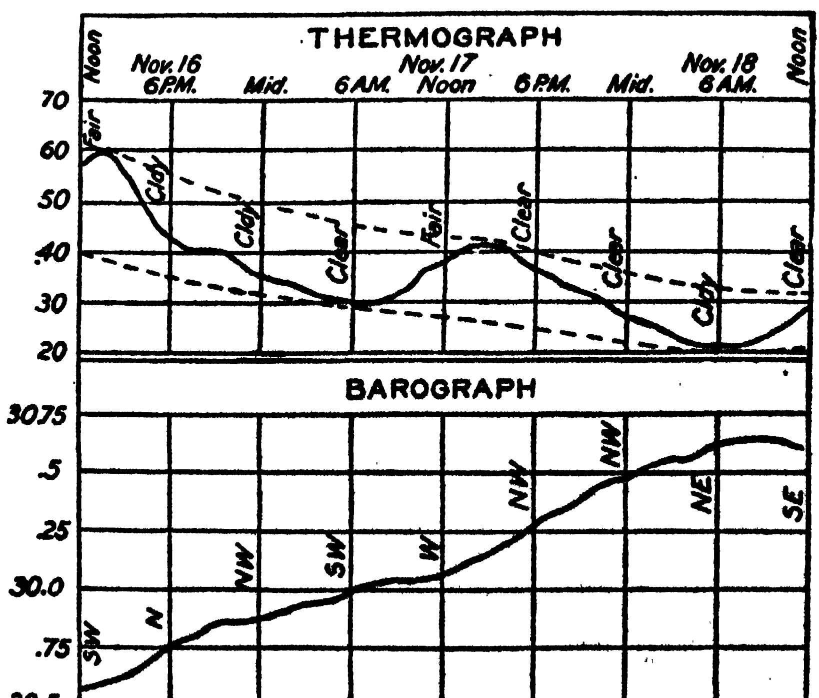

FIG. VII. AUTUMN COOL WAVE (November 16-18).

Another autumn cool wave is shown in Figure VII. The fall in temperature comes in front of an approaching anticyclone; the temperature belt is lowered as a whole, although the sun is shining. The winds, however, are not strong enough and the imported cold not severe enough to extinguish the normal diurnal range (November 17), with its afternoon maximum.

Weather Map Types Favorable for Cold Waves in the Eastern United States

Cold waves accompany well-developed areas of high pressure ("cold wave anticyclones") coming from the Canadian west or northwest and following behind cyclonic areas moving eastward in advance of them. The cold over western Canada may be very intense, but it can not advance far into the United States as a cold wave unless steep barometric gradients are present to make possible the draining off of the cold by the strong northerly and northwesterly winds blowing towards a cyclonic area to the south, southeast or east. As conditions of this sort occur much more frequently over the northern states than in the south, sudden marked temperature changes are most frequent in the north. The severity of a cold wave depends upon many factors. Among these are the intensity of the cold in the "cold wave high;" the size and the degree of development of this high; the pressure gradients; the relative positions, the paths and the rate of progression of the high and the low; the presence or absence of a snow-cover; the amount of cloud; the latitude; the month, etc.

When a large number of cold wave weather maps is examined, it is seen at once that the number of possible combinations of high and low pressure areas as to development, relative positions, paths, rate of progression, gradients, etc., is almost endless. A study of these type maps is of the utmost importance from the viewpoint of the forecaster. In the present discussion, however, which aims only to give the essential facts in their climatic rather than in their meteorological bearings, such details are quite unnecessary. The accompanying figures (VIII-X) are broadly generalized, free-hand composite maps which are intended to illustrate, in a very general way, weather map types which are associated with the occurrence of cold waves in the eastern United States. The sketch maps here reproduced are not copies of any weather maps, and they are not to be taken as representing pressure conditions which must be fulfilled in order that cold waves may occur. They are merely intended to illustrate, in a general way, the kind of pressure distribution which favors a flow of cold air from western Canada into the eastern United States.

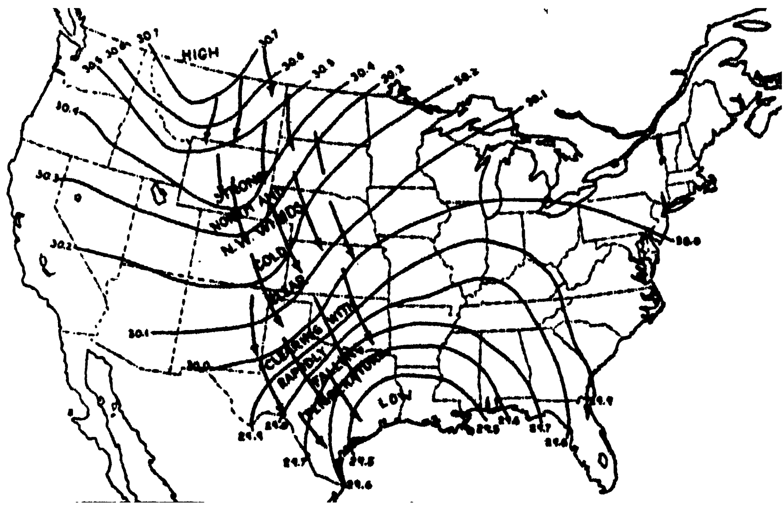

FIG. VIII. COLD WAVE TYPE MAP: I.

Figure VIII shows a pressure distribution favorable for the outpouring of a great volume of cold air from the high pressure area over western Canada, southward over the Great Plains and as far as the western Gulf region (Texas). Severe cold waves reaching far to the south, into the states bordering on the Gulf of Mexico, occur when a well-developed "cold wave high," accompanied by very low temperatures, thus appears in the northwest, and when there is, at the same time, an energetic cyclonic depression over the Gulf or southern Atlantic coast section. As the low (Fig. VIII) moves eastward, and then northeastward along or more or less parallel to the Atlantic coast, the cold wave sweeps eastward with the advance of the northwest winds, crossing the Mississippi Valley, overspreading the southern states and reaching the Atlantic coast. The high, with its low temperatures, normally moves southeastward across the plains, gradually decreasing in energy, and with lessening cold as it later swings eastward across the Mississippi Valley to the central or southern Atlantic coast. Many variations may occur in these suggested conditions. If there is no well-defined depression in the south, the high is less likely to move in a southerly direction, and the area covered by the cold wave will be smaller and will not advance into such low latitudes. If the high is less emphatic, or its cold less severe, or if the gradients are less steep, the cold wave will be correspondingly modified.

The situation broadly generalized in Figure IX is clearly not favorable for the transportation of severe cold into the southern states. In this case the cyclonic depression moves eastward along the "northern track," *i. e.*, across the Great Lakes and down the

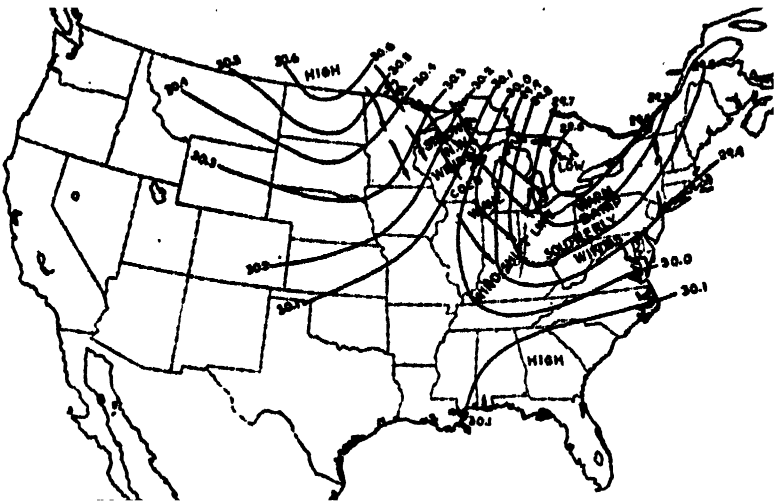

FIG. IX. COLD WAVE TYPE MAP: II.

St. Lawrence Valley, followed by a cold-wave high which follows more or less the same course. The cold wave under these conditions is limited to the northern and central sections of the eastern United States. Many variations of this general type occur. For example, the high may move southward from Canada over the lakes, with a low in the northeast. Under these conditions the northeastern sections, including New England and the middle Atlantic states, are alone affected. In this portion of the country, the cold wave is often preceded by an easterly snowstorm. Again, the smaller and the weaker the depression, and the farther north it is, the less severe and the less far-reaching is the cold wave. Certain large seasonal characteristics are controlled by the characteristics, the paths and the numbers of cyclones and anticyclones. Thus, when in a given winter more cyclonic depressions follow a southern route, being followed by well-developed cold wave highs coming from the northwest, there is a preponderance of cold northerly winds and the winter is likely to be unusually cold. On the other hand, when more depressions follow the northern track, especially if the highs also come from farther south instead of out of the Canadian northwest, there is a preponderance of warm southerly winds over the eastern United States and the winter is likely to be milder than usual.

A weather map which is more or less of a combination of the types illustrated in Figures VIII and IX is shown in Figure X. Here a trough of low pressure extends from the Great Lakes southwest across the Mississippi Valley to the western Gulf. When the gradients are steep, with a well-marked high in the far northwest,

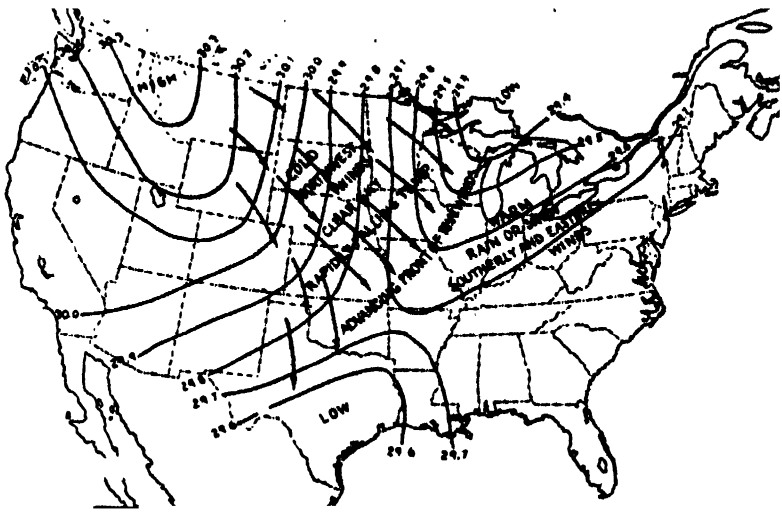

FIG. X. COLD WAVE TYPE MAP: III.

a severe cold wave sweeps the eastern slope of the Rocky Mountains and follows the eastward movement of the low pressure system across the eastern United States.

As has been stated above, these three generalized type maps are not to be taken literally, nor do they in any way show the great variety of conditions under which cold waves occur, and with which the forecaster has to deal. They are merely suggestions. But they may serve to make the matter clearer than would the description alone.

Tempering Effect of the Great Lakes[9]

The open waters of the Great Lakes have a distinctly tempering influence on the bitterly cold winds of a cold wave. This effect extends well on into the spring, when the moderating influence is of considerable economic importance in the fruit districts of the Lower Peninsula of Michigan and in other sections to leeward of the lakes. In a severe cold wave, Kingston and Toronto, on the north shore of Lake Ontario, may have temperatures from 10° to 20° lower than those at Oswego and Rochester, New York, on the opposite shore. This is by no means an infrequent occurrence. Grand Haven, Michigan, on the lee shore of Lake Michigan, similarly often is as much as 20° warmer than Milwau-

[9] See, *e.g.*, E. T. Turner: "The climate of the state of New York," *Fifth Ann. Rept. Met. Bureau and Weather Service of the State of New York for 1893*, 8 vo., Albany, N. Y., 1894, p. 370; *Meteorological Chart of the Great Lakes, September, 1913* (United States Weather Bureau); Mark Jefferson, "The Great Lakes in a cold wave," *Journ. Geog.*, Vol. 12, 1914, pp. 221-223; H. J. Cox, *loc. cit.*, A. J. Henry, *loc cit.*, and elsewhere.

kee, Wisconsin, just opposite, on the west shore. The whole Lower Peninsula is to a certain degree affected, but this influence naturally decreases rapidly on going inland from Lake Michigan. The lee shores of Lakes Huron and Erie show similar effects. The number of cold waves is furthermore distinctly smaller at stations on the lakes than at neighboring interior stations.

Cold Waves of the Western United States

Reference has thus far been made only to the cold waves which sweep across that portion of the United States lying east of the Rocky Mountains. The cold wave chart (Fig. I) shows that the rest of the country, lying to the west of the mountains, is also reached by sudden marked falls of temperature which meet the definition of cold waves. It will be observed that most of the Plateau area between the Rocky Mountains on the east and the Sierra Nevada-Cascade ranges on the west, has cold waves of the same degree of intensity as those of the same latitudes to the east. On the north Pacific coast, on the other hand, cold wave conditions resemble those of latitudes 10° or so farther south on the eastern side of the Rocky Mountains, while California and southern Arizona have cold waves of the same degree as those of the Gulf and southernmost Atlantic coasts.

The great mass of the Rocky Mountains is an effective barrier to the westward flow of the cold air which is carried southward and eastward from the northern Great Plains. Low minimum temperatures occasionally occur over the Plateau under anticyclonic conditions which have drifted eastward from the Pacific coast, the cold air being drawn southward by northerly winds blowing towards a marked cyclonic disturbance. Real cold waves are, however, not common. These are best developed when the high from the Pacific coast is intensified by high pressure over British Columbia.

The Pacific coast not only has a double mountain barrier on the east, against the cold of the interior, but is blown over most of the time by mild winds from the Pacific. Hence its cold waves are few in number, and not severe. They are associated with northerly and northeasterly winds, blowing out of a high over the northern Plateau, or moving southward over the Pacific slope, with a low pressure system preceding it to the southward. Between the two, steep barometric gradients produce a flow of cold air which advances from north to south, down the coast. The occasional frosts of California, which may be of serious consequence to the fruit industry, are the product of local radiation on clear, quiet anticyclonic nights.

American Cold Waves Compared with Those in Other Countries

Cool equatorward-blowing winds on the rear of extra-tropical cyclones are normal, but the peculiar winter conditions in North America, already referred to, combine to give these winds an unusual frequency and also an unusual intensity of cold. A brief comparison of these American cold waves with similar phenomena in other parts of the world is therefore instructive. This matter has been clearly summarized by Professor W. M. Davis as follows:[10] "The winter cold wave of Europe is much less pronounced than with us, and comes from the northeast instead of from the northwest. . . . If a cyclonic center passes far enough south to draw the cold air after it from the low plateau of central France, the wind is called the *mistral* as it flows down the valley of the Rhone to the Mediterranean. . . . Central Europe never feels the excessive cold that is produced by the cold waves of the upper Mississippi Valley. . . . The name cold wave is not employed there, although it is perfectly applicable. Farther east, in Russia and Siberia, where the continental extension allows a more severe winter, the colder cyclonic wind is more like our cold wave; when blowing violently and raising a cloud of fine dry snow, it is called a *buran* or *purga*, corresponding to the *blizzard*. . . . The southern hemisphere has cool waves from the south in the rear of its cyclonic storms; but in the absence of large land areas in high latitudes, the fall of temperature is never as violent as with us; no strong cold waves occur there. The wind of this kind in the Argentine Republic is called a *pampero*. The *southerly burster* of New Zealand also seems to belong here."

It is, therefore, not the nature of the phenomenon but its extraordinary development which gives the winter cold wave of the eastern United States its distinctive character.

The Texas "Norther"

In Texas, and over the region of the Gulf of Mexico in general, the cold (or cool) wave is called a "norther." This wind has all the characteristics of the squall or wind-shift line conditions. It usually follows a general warm, cloudy or rainy spell, comes as a rushing blast from the northwest or north; brings a sudden drop of temperature of maybe 25° or more in an hour, and over 50° or more in two or three hours in winter. Almost incredible stories are told of these temperature changes. Professor Joseph Henry noted that "on one occasion recorded the temperature fell

[10] William M. Davis: "Elementary Meteorology," 8 vo., Boston, 1894, pp. 236-237.

in the course of three hours from 75°F. to a degree sufficient to produce ice an inch thick."[11] The wild sweep of the norther over the open plains is dreaded by all who are outdoors exposed to its chilling fury. Shelter is sought, when possible. Indoors, huge fires are quickly lighted; windows are closed, and the passing of the tempest is impatiently awaited. The sudden fall in temperature is especially disagreeable to human beings, and injurious to stock and to crops, because of the warmth and mugginess which precedes it.

Northers are classed as "wet" and "dry." In the former, the fall in temperature begins before the rain has stopped, and cold rain, perhaps turning into sleet and snow, follows. In the latter, the change to the cold clearing wind comes after the rain area has passed eastward. A wet norther is likely to freeze the rain on vegetation, covering fruits and flowers with an icy coating and causing serious injury. Stock left outdoors also suffers severely. Dark squall clouds rolling up from the north across the sky characteristically precede the norther. "The first appearance of the tempest," wrote Henry, "is a cloud in the north, which approaches the observer sometimes with great and at other times with less velocity, and frequently passes over his head in a series of arches composed of dense clouds separated by lighter portions."[12]

Texas northers occur on steep barometric gradients produced by a well-marked anticyclone advancing over the Great Plains towards the Gulf of Mexico following a low-latitude cyclonic disturbance moving northeastward, with the wind-shift or squall-line characteristics strongly developed. Cold waves and northers are therefore simply, as Ferrel clearly stated, the usual trough phenomena of cyclones, where these are well marked. Or, as Blodget pointed out some decades earlier, in describing northers, they "are but the clear weather side of a revolving gale, like the northwester of the coast of the United States."[13] The prevailing winter pressure distribution over the great central region of North America is itself favorable to the prevalence of northerly and northwesterly winds. The dominant condition is one of north-south gradients from the cold northern interior to the warm Gulf of Mexico. When this condition is intensified by the presence of an especially marked cold wave anticyclone over the northern plains, or a cyclonic storm originating over, or crossing, the western Gulf region,

[11] Joseph Henry: *Ann. Rept. Smithson. Instn. for 1871*, Washington, D. C., 1873, p. 462.

[12] Joseph Henry: *loc. cit.*

[13] Lorin Blodget: *loc. cit.*, p. 30.

or both combined, "the north winds may come down from the plains with great velocity, with a sharply defined head of cloud like a battering ram, replacing warm and stagnant air and causing a sharp and great fall of temperature. These are the well-known Texas 'northers.' "[14] These are, thus, simply temporarily exaggerated cases of the prevailing winter winds, similar, in many ways, to the *mistral* of Europe. The norther of Texas is therefore merely the local designation of cold wave phenomena already familiar through the preceding discussion but, owing to its occurrence in lower latitudes, it is accompanied by less extreme cold. Severely destructive northers are infrequent. Sometimes they advance far southward along the eastern shores of the Gulf of Mexico, and occasionally crossing the Isthmus of Tehuantepec blow onto the Pacific Ocean.

Well-marked northers usually do not last longer than a day or so. The wind then decreases in velocity, shifts to some southerly point, and a spell of fine and warm weather sets in—a transition as sudden, to quote an early writer, as that from "Labrador to Nicaragua." Overcoats and extra coverings are thrown aside; fires are allowed to go out; the winter is forgotten.

Pressure conditions favorable to northers are not limited exclusively to winter, although they are most marked and most frequent then. The norther of spring and fall, coming at a time of prevailingly higher temperatures, is disagreeably chilly. In the summer, on the other hand, the northerly wind is welcomed because of its relatively low temperature. It furnishes pleasant relief from the oppressive heat.

The Blizzard

"The sun at rising was hid behind a red mantel of clouds. The air was unusually moist. A gentle mist deposited moisture on every twig; the mist turned to rain; the rain to snow. About four inches of snow fell. The thermometer was in the vicinity of the freezing-point. About 9 P. M. the wind shifted to the northwest and its velocity increased to about forty miles an hour. It turned cold, and each separate flake of snow became a particle of ice. . . . As the wind would lift fine dust and whirl it through the air, so this body of snow was lifted. To distinguish the form of a human being ten feet away was impossible. A barn, even, could not have been seen twenty feet in front of one. It was a mad, rushing combination of wind and snow which neither man nor beast could face. The snow found its way through every crack and crevice.

[14] Mark W. Harrington, "The Texas monsoons," *Amer. Met. Journ.*, Vol. 11, 1894-95, pp. 41-54.

Barns and stacks were literally covered by the drifting snow, and, when the storm was over, cattle fed from the tops of the stacks. My sheep huddled together in the sheds and many of them were smothered. Persons lost upon the prairies were almost certain to meet with death, unless familiar with the nature of these storms. . . . I learned of many instances where persons were lost in trying to go from the house to the barn, and of other instances where cords were fastened to the house so that, if the barn should be missed, by holding onto the cord the house could be found again. During the blizzard the thermometer ranged from twenty above to ten below. After the storm it reached twenty-five below."[15]

Such, in December, 1865, was a blizzard on the plains of North Dakota, and such is a blizzard in that same region to-day: a sharp, biting, irresistible cold wave gale, with rapidly falling temperature, fine, dry, driven snow and cutting needle-like ice crystals. Its real home is on the northern Great Plains, but it also occurs, with diminishing severity and with lessened frequency, as one passes to greater distances from its northern habitat. In its typical development it is very destructive to cattle exposed to the full fury of its blast in the open plains, and many a farmer and cattleman has been lost in its blinding snow-squalls and its bitter cold. All sense of direction is easily lost; and in the roaring of the gale the sound of the human voice is indistinguishable. "Caught in such a blast one runs the risk of suffocation, the action of the lungs being stopped by the swiftness as well as the intense cold of the wind, while the ice-dust, which penetrates the thickest clothing, is more choking than a summer dust-storm." The blizzard of January 12, 1888, in the Dakotas and neighboring states, came so suddenly after a spell of mild weather that between two and three hundred persons were reported to have lost their lives, being unable to find their way to shelter, and thousands of cattle perished.[16] Winds of over 50 miles an hour were recorded, with temperatures of —20°. The thermometer fell 50° in less than five hours at Helena, Montana, and at Crete, Nebraska, it fell 10° in five minutes.

The blizzard, like the cold wave, is a typical and distinctive American winter phenomenon: an occasional but fortunately not a frequent visitor to the sections where it has its home. Its most favorable opportunity occurs after a snowstorm, when the snow is still loose and soft, and on the steep gradients in the rear of the

[15] C. A. Lounsberry, reprinted from the *Northwest Magazine* in *Amer. Met. Journ.*, Vol. 3, 1886-1887, pp. 112-115.

[16] *Month. Wea. Rev.*, Vol. 25, 1897, p. 15.

retreating low.[17] As in the typical cold wave, the greatest degree of cold (it may be —30°, —40° or even lower) is not recorded until the gale has "blown itself out" under the clear skies and light winds or calms of the succeeding anticyclone. Yet the feeling of cold is far more intense during the gale.

There has been a good deal of discussion as to the origin and the first use of the word *blizzard*.[18] Professor C. F. Talman, of the United States Weather Bureau, has given some attention to this matter. The origin of the word has been plausibly traced to the German *blitzartig* ("lightning-like"), and *blizzard* may first have been used by early German settlers on the northern plains. At any rate, the term *blizzard* does not seem to have been used in a meteorological sense before about 1860. As is the case with any scientific term which has a definite meaning, blizzard should not be used indiscriminately to describe any particularly heavy snowstorm accompanied by high winds. Such a "popular" use of the word is quite general in the eastern United States, and is unfortunate.[19] True blizzards are of very rare occurrence in the latter region.

A memorable storm of this character occurred on March 11-14, 1888, which interrupted for several days telegraphic communication in southern New York, eastern Pennsylvania, New Jersey and southern New England. Snow-drifts of 40 feet in depth were measured in places. The wind velocities averaged 20-25 miles an hour for four days, and at times reached 50-70 miles. Boston, Massachusetts, was so completely isolated that for a day or two communication with New York and other cities was by means of cable via England. The economic loss, on land and sea, ran up into many millions of dollars, and numbers of persons suffered severely from the intense cold, the icy gales and the drifting snow.[20]

17 F. J. Bavendick, "Blizzards and chinooks of the North Dakota plains," *Month. Wea. Rev.*, Vol. 48, 1920, pp. 82-83.

18 See, *e.g.*, C. F. Talman, "Origin of the word 'blizzard'," *Month. Wea. Rev.*, Vol. 42, 1914, p. 692. See also Vol. 26, 1898, p. 562, and Vol. 48, 1920, p. 82.

19 See also *Nature*, Vol. 97, 1916, pp. 261, 280, 301, and Sir Douglas Mawson, "The Home of the Blizzard," London, 1915.

20 Everett Hayden, "The great storm off the Atlantic Coast of the United States, March 11-14, 1888," *Nautical Monographs No. 5, United States Hydrographic Office*, Washington, D. C., 1888; Winslow Upton, "The storm of March 11-14, 1888," *Amer. Met. Journ.*, Vol. 5, 1888-1889, pp. 19-37; A. W. Greely, "American Weather," pp. 225-226.

IS POLIOMYELITIS AN INSECT-BORNE DISEASE?[1]

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THE title of this communication was purposely put in the form of a query, primarily because I am fully aware that many of my hearers do not yet share the view that the spread of poliomyelitis is in any way related to the activities of insects and secondarily because I wish to make it clear at the outset that I shall attempt to present the evidence in a spirit of absolute scientific frankness. Such an attitude seems particularly necessary in view of several rather dogmatic statements which have been promulgated, criticizing the efforts of the medical profession and disparaging the attempts of the health authorities to control epidemics of this disease. I shall, therefore, carefully avoid anything which might lead you to prophesy that the approach of old age may find me hopelessly drifting toward a berth in the Anti-vivisection Society, the League for Medical Freedom, or some equally harmless and constructive cult of "Antis."

A hasty glance at the chart which I have prepared (Fig. 1) will call to mind the several possibilities which we must bear in mind while examining the evidence. The indicated categorical arrangement has been selected simply to facilitate the elimination of methods which do not accord with the observed facts.

Such a classification includes every method so far recognized by means of which infectious diseases are spread, and unless we elect to embrace the doctrines of Christian Science it seems difficult to conceive of any other method. These three groups are not entirely independent, for some diseases like typhoid fever, plague, anthrax, etc., may be acquired by more than one method. Nearly, or perhaps all, of these possibilities have been considered, more or less seriously, by persons who have dealt with either the epidemiological, clinical or experimental aspects of poliomyelitis, and consequently none of them should be summarily dismissed without

[1] Read before Section N (Medical Sciences), American Association for the Advancement of Science, Boston, December 29, 1922.

Conceivable Methods by which Poliomyelitis might be Acquired

1. Through personal contact with an infected person.

Portal of entry: mouth, nose, skin, alimentary or respiratory tract.

1a. Through contact with objects contaminated by microbes derived from a human case.

Same portals of entry, including ingestion with food or water, and inhalation with dust particles.

2. Through contact with infected animals, other than man.

2a. Through contact with objects contaminated by microbes derived from an animal case.

3. Through transmission by insects or other secondary animals, of microbes derived either from man, from other animals, or from contaminated objects.

FIG. I. CONCEIVABLE METHODS BY WHICH POLIOMYELITIS MIGHT BE ACQUIRED.

some good reason. With equal assurance it may be stated that so far none of the methods mentioned has been actually proven, to the satisfaction of all those competent to judge, regularly to prevail. However, as has been already intimated, I am firmly convinced that the method dependent upon an animal reservoir and transmitting insect is the only one which brings into accord the quite extensive knowledge which we now possess concerning this disease.

It seems possible to handle the material more adequately in a few minutes by stating first the conclusions, so for the sake of brevity we will dispense with any dramatic dénouement at the end of the argument. The animal reservoir to which the finger of suspicion points is the rat, and the insect intermediary, the flea—exactly the combination which we know to be responsible for the perpetuation of bubonic plague. The first person to link the rat with poliomyelitis was Dr. Mark W. Richardson, who had become thoroughly familiar with the epidemiology of the disease during its epidemic prevalence in Massachusetts. His first public statement was made in 1916 and a more fully elaborated second publication appeared two years later.[2] My own investigations were begun in Massachusetts in 1911 and have been continued intermit-

[2] Richardson, M. W., '16, "The rat and infantile paralysis: a theory," *Boston Med. and Surg. Journ.*, Vol. 175, pp. 397-400; '18, "The rat and infantile paralysis: a theory," *American Journ. Pub. Health*, Vol. 8, pp. 564-579, 12 charts.

tently since that time, most extensively during the epidemic of 1916 in New York City. Much of the material to be presented is derived from these studies, some of which have already been published,[3] although a great deal has been obtained from other published sources, more particularly those of the Public Health Service, the Massachusetts State Department of Health and the Department of Health of New York City.

I shall attempt to discuss *seriatim* the several most striking peculiarities of poliomyelitis, dwelling more particularly on those which offer reasonable evidence concerning the probable method by which the disease is spread.

Sporadic cases of poliomyelitis have been known to occur more or less regularly in various parts of Europe and North America for many years and they still occur. They appear to arise *de novo,* and were at one time thought to show that the disease was not infectious. Now that its infectious nature is beyond doubt, they are still difficult to interpret and immediately suggest the presence of some non-human reservoir, since rabies, plague and certain parasitic worms have the same disconcerting habit of appearing from whence we could not surmise had we not discovered their animal hosts.

Poliomyelitis was first noticed as an epidemic disease in the last decade of the past century, and it is only since 1905 that any really extensive outbreaks have occurred, first in Europe, especially in the Scandinavian peninsula and almost immediately afterward in North America, as well as in several widely separated parts of the world. Its epidemic prevalence has been strikingly intermittent, with a tendency to exacerbation every second or, more noticeably, every seventh year. If this frequency be repeated, we may soon experience another outbreak in the United States, possibly during 1923, and if such should come to pass, it would seem very probable that a world-wide epidemic wave of poliomyelitis may be under way, similar to the present tropicodemic of plague which began at about the same time. If, on the other hand, the disease remains quiescent for several years longer, we shall have good reason to suppose that no such wave is in progress.

Practically all epidemics of poliomyelitis occur during the summer, and if we examine the seasonal prevalence of the disease we find that it regularly follows a curve closely similar to the one shown in Fig. 2, rising from a minimum in the early spring to a maximum during late summer. Outbreaks involving more restricted

[3] Brues, C. T., '17, "Insects as carriers of infection of poliomyelitis," chapter V of monograph on the epidemic of poliomyelitis in New York City in 1916, pp. 136-168, 2 maps, 5 figs., New York City Dept. Health.

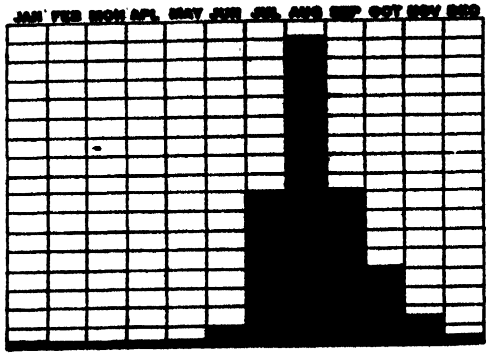

FIG. II. SEASONAL PREVALENCE OF POLIOMYELITIS IN THE UNITED STATES BY MONTHS, 1916. (After Brues, "Insects and human welfare").

areas show a still sharper peak (Fig. 3), but as the peaks succeed one another in time the composite curve rises and falls more gradually. A definite seasonal incidence such as this exactly reverses the equally definite winter prevalence of such diseases as measles, diphtheria and scarlet fever which we know to be acquired through personal contact. Thus, it will be seen from the accompanying chart (Fig. 4) that these diseases gradually begin to gain headway following the opening of schools and the beginning of various winter activities which keep all classes of population indoors and in closer personal contact. They reach their maximum in the

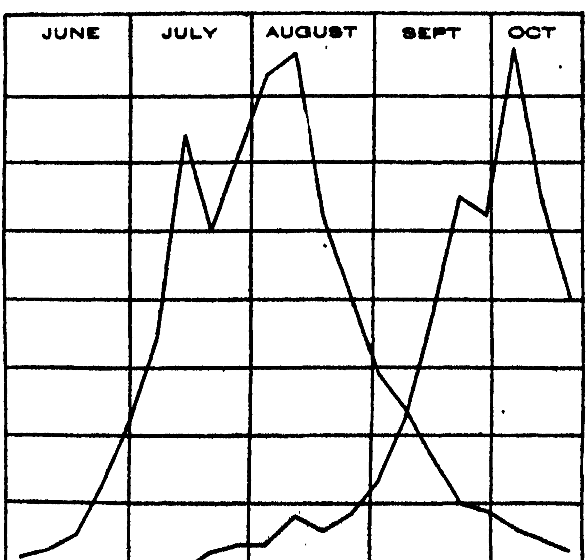

FIG. III. DEVELOPMENT OF TWO EPIDEMICS OF POLIOMYELITIS INVOLVING STRICTED AREAS, TO ILLUSTRATE RATE OF DEVELOPMENT AND SEASONAL RELATIONS. (ORIGINAL).

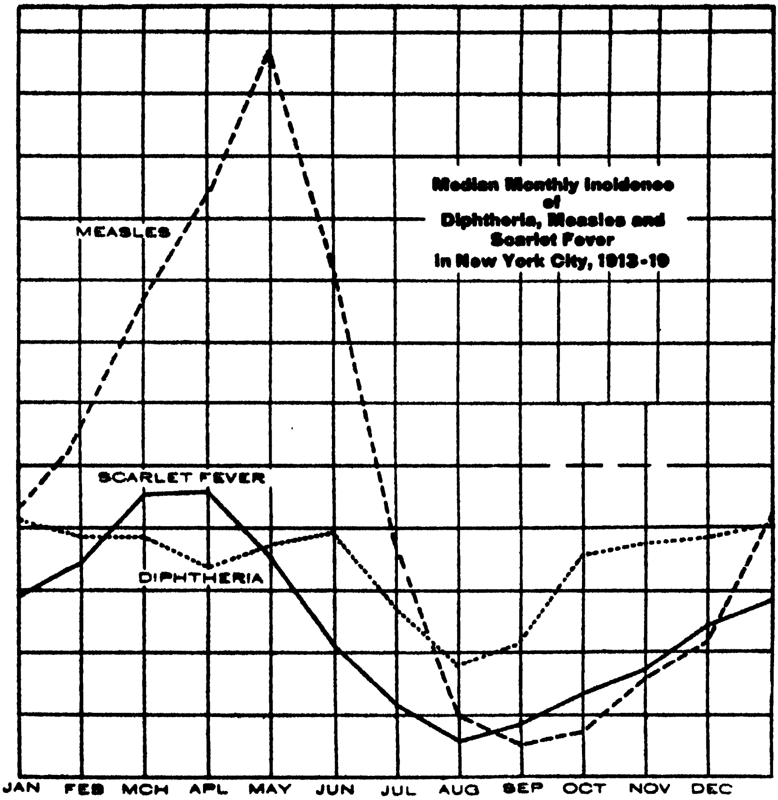

FIG. IV. SEASONAL PREVALENCE OF DIPHTHERIA, SCARLET FEVER AND MEASLES BY MONTHS IN NEW YORK CITY. (ORIGINAL).

spring when poliomyelitis is at its lowest ebb and then rapidly decline, to reach their minimum as poliomyelitis becomes most prevalent.

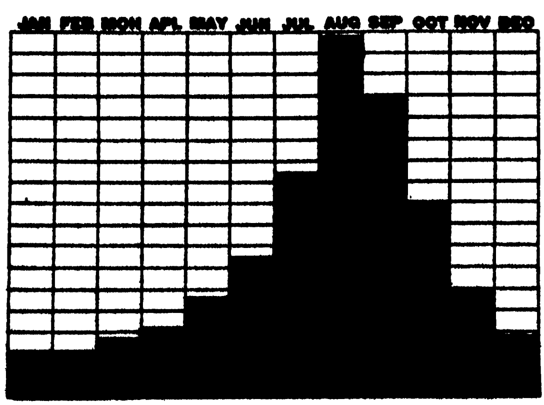

FIG. V. SEASONAL PREVALENCE OF MALARIA IN THE UNITED STATES BY MONTHS. (After Brues, "Insects and human welfare").

On the other hand the seasonal incidence of poliomyelitis coincides closely with that of the known insect-borne diseases, which become prevalent during the season when insect life flourishes. This means, of course, during the summer, except in the case of the louse-borne infections, for human lice find their winter conditions most salubrious. Thus malaria in temperate regions shows a summer and autumnal prevalence as indicated on the chart (Fig. 5). The variation is less than that seen in poliomyelitis, because malaria is most common in the southern states where the warm season is more prolonged.

Bubonic plague shows such a close similarity to poliomyelitis that I must mention it specifically, particularly because we know it to be a disease of rats spread to man by fleas.

The accompanying chart (Fig. 6) shows the seasonal development of two extensive outbreaks of bubonic plague in London and Leyden at the time this disease was prevalent in a cold climate similar to our own, compared with the recent epidemic of poliomyelitis in New York City. I need not dwell upon the similarity of the curves, except to note that the New York epidemic occurred earlier in the summer than is usual with poliomyelitis, and to say that the missing peak of the London plague outbreak, which I have indicated by a dotted line, is accounted for by a wholesale exodus from the panic-stricken city during late August.

The only other diseases that show a similar seasonal prevalence

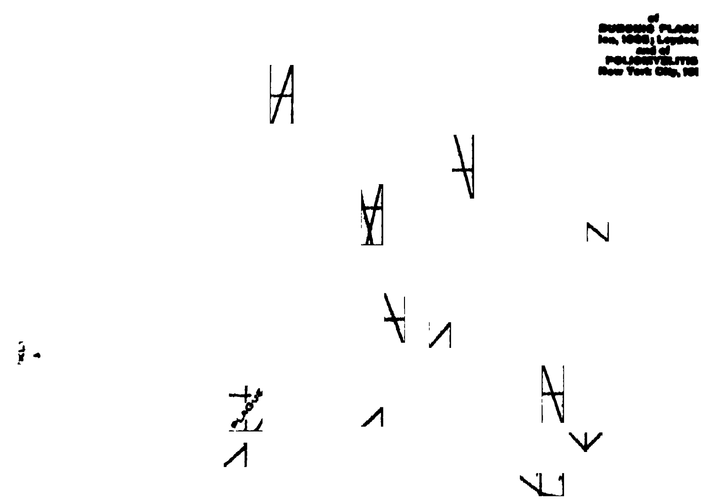

FIG. VI. SEASONAL PREVALENCE OF BUBONIC PLAGUE COMPARED TO THAT OF POLIOMYELITIS. (Original).

are enteric infections, such as typhoid fever and infantile diarrhea. Even here the influence of flies in contaminating food is an important factor and we find, as is shown on the accompanying chart, (Fig. 7) that the summer rise of typhoid fever is much more

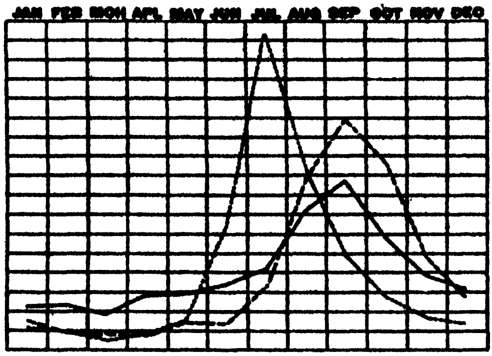

FIG. VII. SEASONAL PREVALENCE OF TYPHOID FEVER IN DIFFERENT PARTS OF THE UNITED STATES.
Dotted line, Alabama; dashed line, Washington; solid line, New York State. (After Brues, "Insects and human welfare").

marked where there is less adequate disposal of sewage. Thus, the season variation is less marked in New York State than in Alabama or Washington. Numerous careful studies have shown, however, that no relation can be established between the sources of food, milk or water and poliomyelitis.

It can be said, therefore, that the seasonal prevalence of the disease lends no support to the theory of contact contagion.

There is one fact relating to seasonal distribution which we must not overlook, as it has been urged as evidence that the disease can not be insect-borne. This relates to occasional winter outbreaks, at a time when most insects are not active. Statistics for 39 such outbreaks are available[4] and we find as I have indicated on the chart (Fig. 8) that they extend through the winter, although more numerous during the early winter months. All are included, although slightly more than half were outbreaks of less than ten cases each, some of these in large cities. Most insects are, of course, practically absent or dormant at such times, but fleas are not, as has been shown by observation, for example in Boston, where one of my former students, Mr. Lyon, found the prevalence of the cat-flea to vary greatly during the course of the year, approaching a maximum in midsummer, declining through

[4] Leake, J. P.; Bolton, Joseph, and Smith, H. F., '19, "Winter outbreak of poliomyelitis in Elkins, West Virginia," 1916-1917 Public Health Reports, Vol. 32, pp. 1995-2015, 5 figs.

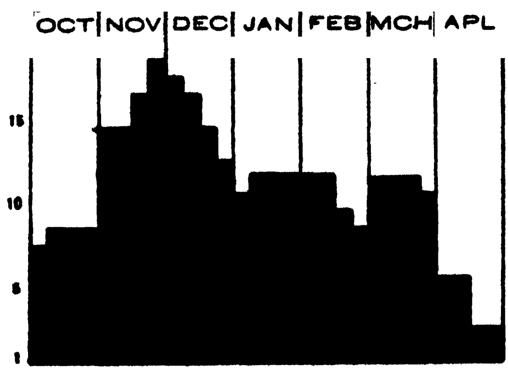

FIG. VIII. THIRTY-NINE WINTER EPIDEMICS (697 CASES) OF POLIOMYELITIS, showing approximate number in progress during each quarter-monthly period. (Original).

the winter to a minimum during March and closely following the curve of poliomyelitis. We also know, of course, that bubonic plague has occasionally been epidemic in winter in cold climates, although this disease usually assumes the directly contagious pneumonic type during the winter season. I wish I had more time to show you that several other characteristics of winter epidemics of poliomyelitis accord with these conclusions.

Summer epidemics of poliomyelitis decline rapidly after the peak is reached, and if they have begun early in the season often disappear before cold weather appears, and before neighboring epidemics have subsided. This would naturally lead to the assumption that a severe outbreak immunizes the susceptible population through an enormous number of slight, unrecognizable or what we may most appropriately term "ambulatory" cases. This also explains nicely the failure of epidemics ordinarily to recur at the same place during successive years. Certain facts show, however, that this apparently plausible assumption can hardly be adequate. Thus we know that the disease always shows a most remarkable selection of children with reference to age. The chart (Fig. 9) shows this selectivity graphically, and we see that the most susceptible age is two years. If extensive immunization occurred, we should necessarily find a greater incidence among younger children in places where the disease was prevalent one or two summers previously. This does not occur, as the curves run so close together that the difference would not be significant, even if it were always in the expected direction, which it is not. We are, therefore, not justified in assuming wholesale immunization of the healthy population to account for the decline of outbreaks, unless we should add the biologically unwarranted corollary

of transitory or ephemeral immunity. Whether we have the immunization of some animal reservoir is, of course, hypothetical, but there must be some underlying factor apparently not human and not meteorological. The biennial increase of poliomyelitis in circumscribed localities is probably due to the same cause. On the accompanying chart (Fig. 10) this is shown as it occurred in Massachusetts from 1907-1910; while the foci in the western and eastern parts of the state were still clearly separated, the comparative prevalence shifted from one side of the state to the other in alternate years, a characteristic also noted elsewhere and apparently not explicable on the basis of a purely human disease.

The geographical and topographic relations of poliomyelitis present several features which are very characteristic and which, as we shall see in a moment, do not lend themselves to explanation on the basis of contact infection.

Rural communities are almost invariably more severely affected than urban ones. This has been observed everywhere that the disease has become epidemic. Even in New York City during 1916, the incidence of poliomyelitis in the several boroughs of that city was almost exactly in inverse proportion to the density of popula-

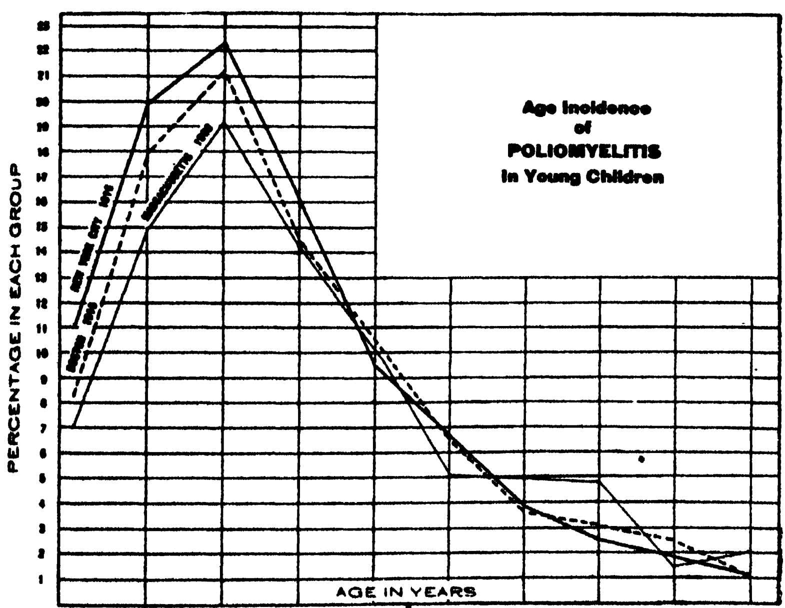

FIG. IX. INCIDENCE OF POLIOMYELITIS AMONG CHILDREN, WITH REFERENCE TO AGE, IN THE CASE OF THREE OUTBREAKS.

One (Massachusetts, 1909) was at the beginning of its epidemic prevalence, another (New York City, 1916) after the presence of the disease for some years in very small amounts, and the third in a locality (Boston, 1916) where the disease had been more or less epidemic for a number of years. (Original).

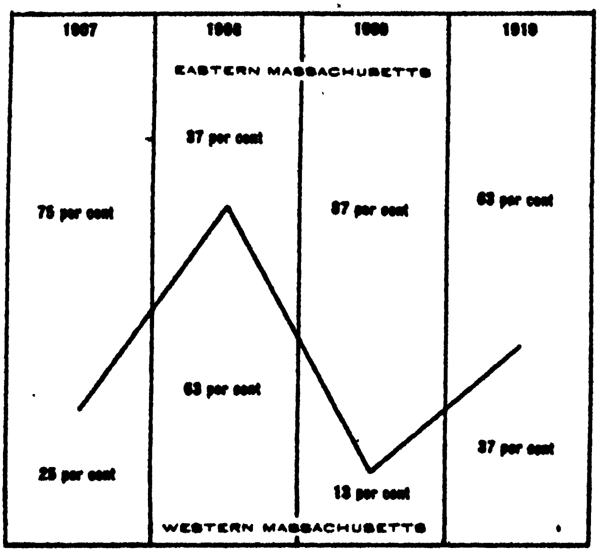

FIG. X. CURVE ILLUSTRATING THE BIENNIAL RISE AND FALL OF POLIOMYELITIS IMMEDIATELY FOLLOWING ITS APPEARANCE IN EPIDEMIC FORM IN MASSACHUSETTS.

The percentages above indicate the proportion of cases in the eastern part of the state each year, and the percentages below show the proportion of cases developing in the western part of the state. (Original).

tion. It was highest in Queensboro and Richmond (Staten Island), less in Brooklyn and still far less on the thickly populated island of Manhattan, which includes one of the most densely crowded areas in the world.

It will be noted that while the epidemic severity, even in the parts of a large city, does not vary with the density of the human population, it does appear to follow the rat population. This is shown perhaps more clearly by another much smaller area. This is the lower East Side, the most crowded part of the city, where any disease spread by contact should become rampant, but its incidence rate was lower than that of any entire borough in the city. Also, we must note that this area is bounded on two sides by the water-front of the east river and on a third by 14th Street, which carries a large sewer. Along these sections the incidence was exactly twice that which prevailed in the sections not directly adjacent to the water-front. The conditions here, which I have been able only briefly to outline, directly contradict any theory of personal contact and suggest something associated with wharves, sewers and the water-front—namely, rats.

When we look still more minutely at the spatial distribution of cases in a city like New York we are confronted by another anomalous condition. On a spot-map, where each case is indicated

by a dot, we find that there is a very evident tendency for the cases to group themselves in city blocks, that is to say, in the quadrangles of contiguous buildings, each separated by streets. Under such unfortunate conditions the only playgrounds for children are the streets, and this results in the mingling of the occupants of adjoining houses and of those on opposite sides of the street, while there is far less contact between those living on opposite sides of the block. Nevertheless, poliomyelitis spreads around or through the block more commonly than it crosses the street. The bearing of this observation on contact is obvious, and we are led to look for some agent that travels by more unconventional routes.

When Johnny suddenly shows up with a nice case of measles, chickenpox or some other disease, we immediately begin to wonder where he "caught" it, and nine cases out of ten we can single out some unfortunate playmate who "gave" it to him. Such is not the case with poliomyelitis; it comes out of a clear sky, so to speak, although when epidemic there are usually cases not far away—somewhere in the neighborhood. In other words, it is impossible to establish the probability of direct contact with a previous case in more than a small proportion of cases. To use the words of one group of investigators (Lavinder, Freeman and Frost) who rather lean toward the idea of contact infection, "in individual cases contact, either direct or indirect, with a previous case of poliomyelitis could but rarely be established, and in many instances the possibility of such contact could be satisfactorily excluded." Careful investigation of the cases on Staten Island in 1916 by these authors who searched for every possible contact showed that 29.2 per cent. of all cases (paralytic, abortive and suspicious), gave evidence of direct or indirect contact (through a third healthy person), positive or probable with a previous case, either paralyzed, abortive or suspicious. Ordinarily the percentage is much less, from 3 to 8 per cent., and we must remember that in diseases like plague, yellow fever and malaria where contact has nothing to do with infection, it can nevertheless be demonstrated in many instances.

Similarly, secondary or additional cases in the same family do not occur so commonly as they do among the known contagious diseases. This is shown graphically in the chart (Fig. 11), where we see on the left-hand side that scarlet fever and diphtheria are much more apt to attack an additional member of the same family than is poliomyelitis. This statement might be dismissed with the reply that poliomyelitis is less contagious, but the right-hand half of the chart shows that such a simple explanation will not suffice,

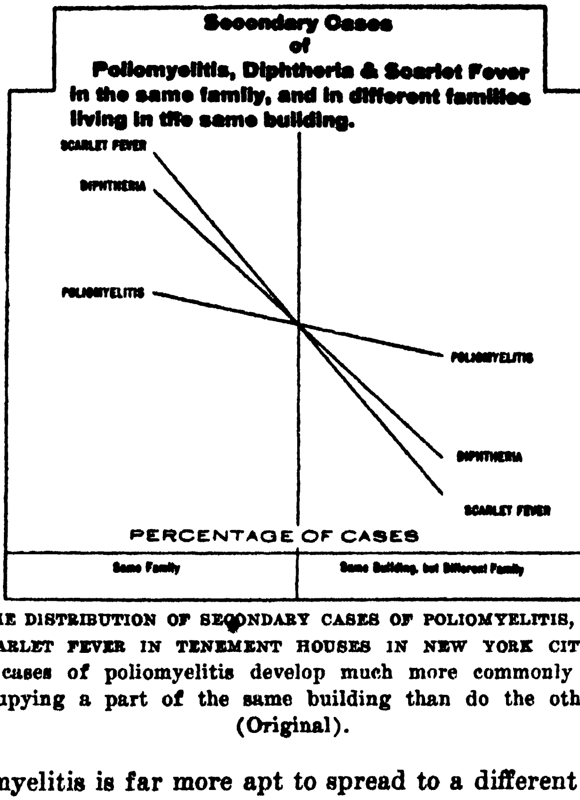

FIG. XI. THE DISTRIBUTION OF SECONDARY CASES OF POLIOMYELITIS, DIPHTHERIA AND SCARLET FEVER IN TENEMENT HOUSES IN NEW YORK CITY, 1916. Secondary cases of poliomyelitis develop much more commonly in another family occupying a part of the same building than do the other diseases. (Original).

for poliomyelitis is far more apt to spread to a different family in the same tenement than are the other diseases mentioned; that is to say, it tends to be distributed through a building with but little reference to the family unit. The very definite age selection of poliomyelitis undoubtedly influences this proportion somewhat, but there is plenty of susceptible material in such prolific groups and as is well known, diphtheria shows almost the same age selectivity as poliomyelitis. Thus we can hardly avoid the conclusion that the infective agent is not subject to the restrictions which limit human contact in tenements, but that it spreads through walls and floors just as it wanders through the larger city blocks.

The failure of the disease to spread in hospitals to nurses, attendants or other patients has been noted incessantly by various observers who have ordinarily attributed it to the precautionary technique of the modern hospital, which does not, however, entirely prevent the spread of the well-known contagious diseases.

The progress of epidemic spread of poliomyelitis has been carefully followed in a number of outbreaks in Sweden, in Massachusetts and in New York City and the adjoining states. It always moves with extreme deliberation and even in the great metropolis showed no tendency to acquire the speed mania which afflicts the

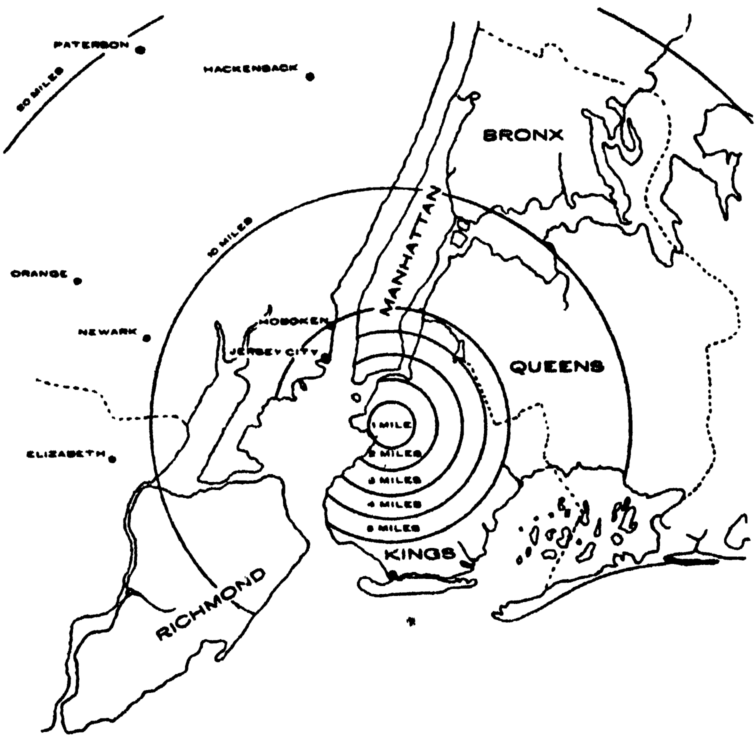

FIG. XII. MAP ILLUSTRATING THE RADIAL SPREAD OF THE EPIDEMIC OF POLIOMYELITIS IN NEW YORK CITY, 1916.

The epidemic had its origin at the center of the inner circle. (Redrawn from Lavinder, Freeman and Frost).

human population. The first cases occurred in Brooklyn near the head of the old Gowanus Canal, a tidal estuary extending from the water-front, best compared to the Chicago River in its palmy days. That its origin in this rat-infested area is a mere coincidence is, of course, quite likely. From the original focus, the epidemic spread generally into the surrounding parts of Brooklyn, and a number of more or less discrete secondary foci were established during the course of the following weeks. This spread was carefully studied by Lavinder, Freeman and Frost,[5] and their results, which may be best understood by reference to one of their charts (Fig. 12), are of extraordinary interest. Dividing the area into zones with the first group of cases at the center it became evident that the spread of the epidemic was markedly radial in character.

[5] Lavinder, C. H., Freeman, A. W., and Frost, W. H., '18, "Epidemiological studies of poliomyelitis in New York City and the northeastern United States during the year 1916," *Bull.* United States Public Health Service, No. 91, 274 pp., 46 maps, 21 charts, 51 tables.

Obtaining an average date of onset for all the cases in each zone and thus obtaining a "median" case, it appeared that these median cases succeeded one another in time, so that the crest of the epidemic passed from within outward at a slow but accelerating rate. Thus it required several weeks to attain the periphery of the five-mile zone, and thirty-five days to travel to the outer zone of the city. Coincident with this movement the prevalence of the disease declined in the district first affected, while it was increasing in the more recently affected zones.

Such radial spread is not comparable to the movements of the population of Brooklyn and is incompatible with their diurnal migrations into New York, for the spread of the disease westward was delayed by the East River and not hastened by the extensive movements of the people who cross the river. When the disease did appear in Manhattan, the simultaneous foci were widely separated.

Although the spread of the New York epidemic of poliomyelitis was not in accord with human movement, either in time or space, it coincides with the known migratory habits of rats. To forestall your conclusion that this statement is a figment of my own disordered imagination, allow me to quote a statement of the unprejudiced "Indian Plague Commission" concerning an epidemic of bubonic plague in Lucknow, an Indian city of over 200,000 inhabitants:

> When the commission started work in Lucknow in January, 1911, the city was infected by plague for the first time since 1907. The first cases were reported in the month of November from Hassanganj Ward, which, as has already been mentioned, includes several more or less scattered villages on the northern side of the river Gumti, which separates Hassanganj Ward from the rest of the town.
>
> Infection was confined to that side of the river till the month of January. In the latter end of that month, infection appeared more or less simultaneously in all the five remaining wards of the city. The epidemic reached its height in the month of April, after which it rapidly declined. . . . It will be noted that the epidemic did not reach its height simultaneously in all the wards of the city. Those earliest infected exhibited the highest plague death rate in the month of March, those later infected not till the month of April. The disease was actually declining in the two wards, Ganeshganj and Hassanganj, at the very time it was working up in the adjacent wards of the city.

I might mention a number of other matters, but the several points which have been so briefly outlined show the many difficulties and contradictions which make it extremely difficult and to my mind impossible to understand the epidemiology of poliomyelitis on the assumption that it is a disease spread by personal contact. These difficulties have been appreciated very generally by all those

who have studied the disease with the exception of laboratory workers, and to the work of these investigators I shall refer in a moment. The failure of the personal contact theory to meet the requirements has led to the assumption that poliomyelitis is spread mainly by healthy carriers, or third persons harboring the virus, who may distribute it in a more infectious condition than those actually in the prodromal or acute phases of the disease. This accounts for the fact that contact with a severe case involves little chance of infection, and explains to some extent, although very imperfectly, the spatial spread of epidemics. Many features, however, as we have seen, show it to be inadequate, and it appears to find little support by analogy with other diseases.

As is well known, poliomyelitis can be produced experimentally in monkeys, with virus derived from human cases. Portions of the spinal cord from human autopsies injected into the brain, peritoneum or general circulation or rubbed into the scarified nasal mucosa cause infection and by repetition the disease may be passed on indefinitely to other monkeys. In them it shows the typical paralyses and histological details seen in human cases.

Similarly, it has been found possible to cause the disease in monkeys by the intracerebral or intraneural injection of less active virus contained in the blood, nasal or oral secretions or dejecta of human cases and even from the secretions and dejecta of persons closely associated with acute cases. However, as with the similarly neurotropic virus of rabies, the virus of poliomyelitis, in whatever form, must be introduced within the tissues. Thus no portal of entry has been found in laboratory experiments which could function under natural conditions without some medium for inoculation, such as abrasions of the nasal mucosa or the bites of insects or other animals. As we have seen, the only supposition which is in accord with the epidemiological data would seem to be the one relating to insects and very particular insects at that. Many experiments performed with insects have been ill-conceived, since many kinds, such as lice, bedbugs and houseflies, on account of their seasonal distribution, method of migration, etc., could at most be only auxiliary factors. As you doubtless know, I was at one time led to believe, on the basis of less complete epidemiological knowledge, that the stable-fly fulfilled all the requirements. Other facts that have more recently come to light show certain discrepancies, and although transmission experiments with this insect have been successful when bodily parasites such as fleas and lice were not eliminated, several similar attempts have failed when fleas and lice were carefully excluded. We have shown, however, that poliomyelitis has none of the ear-marks of a louse-borne disease.

Several attempts to infect rats and other rodents, such as rabbits and guinea-pig, by present laboratory methods have yielded rather inconsistent and variable results. The clinical or histological picture of poliomyelitis is rarely or never present in a typical form in these animals, but rats show a high death rate following injection into the brain and peritoneum of cord or brain-emulsions from poliomyelitic monkeys. Passages through other rats are successful in the same way, but the transfer back to monkeys has not been accomplished.[6]

A further application of experimental data to the present discussion does not appear profitable, but I should like to point out some of the difficulties that beset the experimenter:

1. Experimental poliomyelitis has so far been produced only by the injection of virus through what are, in most cases at least, wholly unnatural channels.

2. The natural progress of the infection in spontaneous human cases may involve tissues such as the blood, which are omitted or bridged over in experimental work.

3. He can not know positively that the virus is a simple organism of uniform potentialities, rather than one of greater complexity represented only by certain stages in the material with which he deals.

I have wearied you already with too many details, some of which may seem irrelevant, but taken together they show that there is at least a strong probability that poliomyelitis is an insect-borne disease.

In closing I shall risk the chance of deeply offending the dignity of my audience by quoting a few passages concerning bubonic plague from an old edition of that much-maligned compendium of knowledge, the Encyclopedia Britannica, published in 1885. This article is extremely illuminating, not in the interpretation of the facts which it contains, but as an illustration of the impossibility of interpreting them before the exact nature of plague and the method of its transmission were suspected. These remarks also differ in lacking the finesse of modern medical verbiage, but if you will promise not to read between the lines and to visualize "healthy carriers" in place of clothing, the analogy to many of our present ideas concerning poliomyelitis will be apparent. The interpolated remarks on poliomyelitis from recent authoritative accounts are included for direct comparison.

[6] Stimson, A. M., '18, "Attempts to induce poliomyelitis in small laboratory animals," *Bull.* Hygienic Lab. U. S. Pub. Health Serv., No. 111, pp. 31-34.

By whatever means, there is no doubt that plague is diffused or spread from one place to another, and that its spread is connected mediately or immediately, in most cases at least, with human intercourse, but this diffusion appears to take place as a rule slowly, and to be effected by the formation of new foci of contaminated atmosphere.

The crest of the epidemic [of poliomyelitis] passed from within outward, requiring approximately 35 days to travel from the original focus to the outer zone of the city [10 to 15 miles away]. . . The simultaneous foci set up, for example, in Manhattan were widely separated.

The plague of 1665 was widely spread over England, and was generally regarded as having been transmitted from London, as it appeared a month later than in the metropolis, and in many cases the importation by a particular person could be traced.

New York in 1916 formed the original focus of an epidemic of poliomyelitis which ultimately extended and involved a wide area of territory. . . . In a significant proportion of the more isolated rural cases, where no definite contact could be established with a previous case, a history was obtained of association with known infected localities. . . .

It is a very momentous question whether the contagion [of plague] is capable of being conveyed by clothes and other objects that have been in contact with the sick.

Outside the human body, the living virus [of poliomyelitis] has been demonstrated in nature only in the dust of rooms occupied by the sick and presumably contaminated by their secretions; and possibly, though far less convincingly so, upon articles recently handled by the sick.

It is generally agreed that plague is transmissible to another country only when it is epidemic and not from sporadic cases.

The development in poliomyelitis of the power of epidemicity in all countries affected has been quite similar—first sporadic cases, then small groups, succeeded in time, as the disease gained force, by larger groups, until, as a rule, the disease has culminated in outbreaks of significant proportions.

The singular resemblance of these quoted passages illustrates incidentally several of the similarities between plague and poliomyelitis, but shows more specifically that our present explanation of the spread of poliomyelitis through contact partakes of the same vague uncertainty that pervades the older account of plague. It fails to explain several important and well-authenticated epidemiological characteristics of the disease, and we must regard it at best as a weak working hypothesis.

THE HISTORICAL BACKGROUND OF MODERN SCIENCE[1]

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The Need of Starting Right in the History of Science

THE history of science is practically a new field both for the scientist and the historian, and so, like a spotless sheet of white paper or an untrodden expanse of glistening snow, is a very tempting thing upon which to make marks or tracks, and I have to confess to being one of those who have been unable to resist this temptation. But it would obviously be advantageous if we could use this opportunity to open up a new field by opening it up in the right and best way, and not indulge in tentative activities of a kind which will only handicap and mislead those who follow us. The investigation of this new field should at least be up to date in availing itself of the latest achievements and most advanced methods both of historical scholarship and scientific research. Such a joint conference as this, then, where scientists and historians may take counsel together, seems a very fitting occasion for discussing what are the best methods of attack in dealing with the history of science. My acquaintance is limited for the most part to what may seem at first sight the remote historical background of the so-called middle ages and beyond; but inasmuch as only about one millionth part of the whole evolutionary process of this world and life therein has been added since the close of the middle ages—and when did they close, anyway?—perhaps I may bring to you from the study of that period, which is thus in reality very close and near to us, some warnings and suggestions.

The History of Science Should Be Studied Scientifically

Historians owe a great debt to the natural and exact sciences for the conception of a science of history. Although some historians maintain that such a science of history is impossible because we can not experiment with the past and because the extant

[1] An address delivered at the joint session of Section L, American Association for the Advancement of Science, with the History of Science group from the American Historical Association, Thursday, December 28, 1922, at Cambridge, Massachusetts.

remains are so fragmentary, and that therefore they are at liberty to reconstruct or imagine the past as they please, the majority of historical workers feel that these considerations only make doubly important the very thorough gathering and exceedingly careful and accurate measurement and interpretation of such materials as we do have. We feel the need as much as or even more than you of thorough scientific training, equipment and scepticism. We have to use the microscope of minutely sensitive critical insight, the balances of delicately suspended judgment and absolutely dispassionate appraisal. I say this because it has seemed to me that sometimes scientists, when they first enter the historical field, tend to kick up their heels, be exuberant in their new-found pasture, and follow the example of certain historians who run snorting around at large instead of yoking themselves to the heavy plough of scientific historical method and drawing a straight furrow. The history of science must be studied scientifically. One must no more follow authority than one would in the laboratory. One must accept only such scientifically demonstrated results as one would in a scientific paper after testing them further for oneself. As the laboratory equipment and method of the sciences are but a thing of yesterday, so great caution is required in using the history books of a previous generation. And in a subject so full of uncertainties and marked by relativity as is history, one must hesitate long before selecting this or that factor or personage for special emphasis.

Relation of the History of Science to the History of Civilization

Most of us will probably agree that history in the narrow sense, as presented and covered in courses given hitherto by the departments of history in most of our institutions of learning, has little vital connection with the history of science which relates rather to the history of civilization. I will not stop to define this phrase, "history of civilization," as I think all of us here are in fundamental agreement as to what constitutes civilization. I find myself, for example, interested in almost exactly those same books on, and sides of, civilization other than science proper which Dr. Sarton includes for consideration in the pages of "Isis." It is true that books have been published recently with civilization in their titles which in substance are still mainly repetitions of the old political and military history. But the mere change in title is significant of a change in interest, and the main reason why these recent books do not make their contents conform better to their covers is that their authors did not possess the broad appreciation

or patient industry to collect the necessary new material for a true history of civilization. Indeed, any philosophy of the progress of civilization, adequately supported by detailed researches and acceptable in its general outline to common sense, is as yet as much in its infancy as is the history of science itself. And very naturally so; for how can the history of civilization be adequately comprehended when the history of science remains so largely unknown? The history of art has recently received the attention of many specialists and publications and made rapid forward strides; the histories of literature and philosophy made their debut still earlier; but even these departments of the history of civilization will be incomplete until the true relations of the science of the past to them is made more clear.

The Danger of Sweeping Generalizations

Indeed, almost all histories of art, literature and philosophy that I have read, however scholarly they may have been in their own special spheres, have shown a weakness not merely in regard to the scientific knowledge of the past but also in regard to the main current of history and civilization. Briefly, they have said and assumed too much, and, instead of sensing the relativity of history, have indulged in unwarranted generalizations. For instance, they speak with altogether too much confidence concerning "the spirit" of any age in question. Yet the spirit of any age would seem almost its most elusive feature; the most difficult to capture, define and measure; rightly to be estimated only after all the facts are in and have been carefully weighed and classified; and furthermore, unfortunately, the one point on which rhetorical and impressionistic but not overscrupulous historians or word-painters of the past have been most likely to give vent to unrestrained imagination. The ordinary reader accepts eagerly these easy generalizations and such brief catch-words to describe whole periods as Renaissance, Scholasticism, Medievalism, Reformation, Age of Reason, Modern Progress. But they are rather more misleading than convenient, and to the trained eye usually betray a lack of detailed acquaintance upon the part of their users. Certainly the fitness of such rough designations has never been scientifically demonstrated, and they must not be taken as axiomatic. On the contrary, most recent detailed research has tended to disprove them, except—and here comes the pity of it—in those numerous cases where it has unquestioningly based its further painstaking investigation of minor points upon this false foundation of sweeping generality. The very notion that history falls into periods violates the great law of historical continuity, as Professor James

Harvey Robinson was pointing out when I began graduate work in history twenty years ago; but while almost every one agrees to this now, almost every one also still continues—thereby admirably illustrating the law of historical continuity itself—to assume the periods as a basis of classification, argumentation and generalization, and I somewhat regret to note that even you scientists, despite your faith in gradual and unceasing evolution, keep presenting us with additional periods, Pre-Chellean, Mousterian, Aurignacian, Solutrean, Magdalenian and what not.

History of Civilization Has Not Yet Been Fully Investigated

Another reason why we do not yet have a complete notion of the course of civilization in general, against which we may set the history of science in particular, is that the early history of mankind and of the ancient civilization of the near east has only recently been brought to light, while China and India have scarcely been taken into account in our western efforts to trace the evolution of human civilization. Yet their long unbroken development, their voluminous literatures, assuredly furnish most illuminating illustration all along the line—parallel cases or contradictory cases as the case may be—and must be included before we shall have a satisfactory synthesis. It would, therefore, seem the part of discretion for the historian of science to refrain for the present from all sweeping generalizations concerning such matters as the spirit of an age or the character of civilization at large, and above all not to take such generalizations from antiquated authorities or from books that never were authoritative, but rather limit himself strictly to what scientists were doing and thinking in the past, and thus supply a true foundation for a later unprejudiced synthesis.

Inner Mental Development More Important Than Outward Circumstance

In any case has not the history of science through the ages depended more upon the development of the scientific mind than upon outward circumstances? Superstition and folklore, magical practice and belief, divination of the future, do not appear to have been forced upon man by outward circumstances but to be an inevitable stage in the development of the human mind, though of course they may come to be sanctioned and maintained by society. The same would seem true of science itself. On the other hand, war and cruelty, persecution or neglect of unusual individuals—persecution is preferable as an advertising medium to neglect—and intolerance in one form or another have been pretty much a constant quantity in all ages of human civilization thus far; and

when the historian dwells upon them inordinately in any one period, it is apt to be a case of hypocritical indication of a mote in another's eye when he might better be employed in removing a beam from his own. We, who invent poisonous and deadly gases to slaughter mankind wholesale, hold up our hands in horror at the more discriminating activities of the Holy Inquisition, which as a matter of fact very seldom persecuted any one for scientific views, but medieval church councils forbade the use of military engines against Christians as being too murderous and perhaps kept Greek fire out of western Europe, therein displaying a medieval prejudice against inhuman war inventions which two nineteenth century historians of artillery somewhat impatiently ascribe to "ignorance, religion and chivalry."

The Conflict of Science and Religion Has Been Too Much Dwelt Upon

It would indeed be well if historians of science from now on could forget a little—if Mr. Bryan and Kentucky legislators will let them forget—the concept of a conflict between science and religion. I do not mean to say that there has not been a conflict and that it is not still irritating, but it does seem to me that it has been overemphasized and is not the *leit motiv* of the entire history of science or of the history of science since the beginning of Christianity. Pagan Antiquity persecuted its scientists more than the Middle Ages did theirs. And Mr. Bryan is not a relic of medievalism as this morning's paper says someone intimated at these conferences yesterday. Mr. Bryan is a distinctive product of our modern civilization. There are many other things that have conflicted and still conflict with science besides religion, and an unscientific attitude is displayed in plenty of other places than churches. One might, for example, wax eloquent over the conflict in our own time between science and advertising, the trashy popular reading, not literature, which goes with advertising, the popular education which trains the masses not in useful trades but in just enough book-learning so that they may read the daily paper and cheap magazine and may be taken in by advertising, and trains the few who go on to university courses in business psychology just a little more so that they can fool the others by advertising. If half this time and space and effort that is now given over to tempting and deceiving and stimulating and glutting the appetite of the consumer were devoted to training and encouraging the producer, what art we might be enjoying instead of constantly consuming more than we produce and robbing future generations of their natural resources. For twenty years now I have been

studying the magic of the past, and, believe me, some of the present generation of advertisers need yield nothing to the past generations of magicians in their trust in the power of mere words and images and agreeable mental illusions and delusions, in their theory of some occult virtue of salesmanship, and in their exploitation of popular lusts and credulity. The chief respect wherein they differ from the old magicians is that these advertisers have less regard for concrete objects and for laws of nature. It is indeed painful to see institutions of higher learning begin to pander to this popular immoral and unscientific demand from the business world. Still it need not give us a great deal of concern; let that sort of people teach advertising if they like; so long as they keep out of history and science, it is so much gain. Does this diatribe against modern advertising seem to your cool common sense and sane judgment a trifle overdrawn—perhaps even out of place in a scientific discussion? Very good! But let me add that it is not a whit more so than are most animadversions by historians of science upon the medieval church.

THE PASSING POPULAR MILIEU IS TO BE DISREGARDED

Moreover, I look back to the centuries before popular education was supported by printing, and in the second century I hear Galen complaining that there are not five persons known to him who really prefer truth to seeming; I hear Boethius in the sixth century grieving that the vulgar have torn off philosophy's robes and left the essential truth naked and crying for covering; I hear William of Conches in the twelfth century grumbling at the way that the bars have been let down in the educational system in his day, and even ceasing to teach because of the onslaught of the unskilled multitude; I hear Roger Bacon in the thirteenth century embittered by the facile successes of the boy theologians. But where to-day are those popular, superficial, successful contemporaries of whom Galen, William, Roger and other real scholars and scientists in the past complained? Gone! absolutely forgotten as individuals, very probably not a single manuscript written by them preserved, unmentioned in the writings which are extant except collectively and unfavorably; in short, but for the discontented grumbling of the Galens, the Williams and the Rogers we should have no evidence of their *quondam* existence. But Galen, William, Roger and their peers live on. In the passing world of talk rank weeds may flourish, but in the enduring world of books there is a survival of the fittest. The trouble with us historians has been that we waste our time in writing histories of politics for statesmen who never look into a history until they come to write their own memoirs, or economic

history for business men who read nothing but the stock market reports, instead of writing histories of books for readers. Historians of science need give even less attention to the fleeting ghost-like "spirits of the times" to existing society and contemporary custom, to political and economic conditions, while they may center attention the more on the enduring and progressive process of human thought. We can trace our intellectual ancestors a long way back. Each new war blots out the interest in the previous war; each change of ministry relegates once familiar figures to a gloomier obscurity; but every future scientist can find common ground of sympathy with those men of old. History, as Osler so well said, is simply "the biography of the human mind."

The Progress of Thought

The history of science, when sufficiently disclosed, should throw a great light on the problem how new ideas and theories gradually evolve out of the previous common stock possessed by mankind. In analyzing past writings and surveying past centuries I have been impressed by the slowness and gradualness with which ideas change, and by the really very small number of ideas which men have thus far entertained or expressed, much as man has domesticated only a few animals. Many men of learning, and famous ones, too, have seemed to repeat ideas parrot-like, and I can not convince myself that this is merely patristic or scholastic; it has seemed to me everlastingly human. There are also, it is true, minds that seem more restive, skeptical, experimental, original, creative; but when any new conception emerges, it often appears to be not the product of a single mind but rather to have been entertained simultaneously by several contemporaries. Thus, when the time is ripe, a new idea takes hold of the more progressive and open minds of that generation. And I wonder if we have sufficiently allowed for the wide and rapid spread of ideas in the past, despite linguistic barriers and primitive methods of communication. After all, the ancients represented fame and rumor as swift. If eels migrate incessantly from one region of the Atlantic to inland streams and ponds of Europe and America, if germs of disease carried the Black Death from Tartary to England, if Chinese jade went through to Troy four thousand years ago, would not winged words and valuable ideas spread, too? The ideas were fewer than the eels or the germs, it is true, but are they not also more indestructible? Ideas change, but it was a medieval writer who said, "Science always is making acquisitions and never grows less."

Importance of the Middle Ages

Already I have ever and anon been defending the so-called middle ages, and my next point will be that they constitute the immediate and most essential background of modern science. It will not do to trace the story of science through the classical period and then, in the words of a book on the Septuagint which I have just been reading, "resume . . . after a blank space of, roughly a thousand years with the invention of printing." No, we must abandon the absurd prejudices against and ignorance of the middle ages which we have inherited and poll-parroted from narrow Italian humanists, from Protestant reformers and Fox's Book of Martyrs, or from the eighteenth century deists, Voltaire and Tom Paine; we must correct and expand our notion of "modern progress," and subject the period before America was discovered to impartial open-minded scientific investigation. The historians of art have done this and found Gothic architecture first in quantity of noble remains and second to none in quality. The philologists have done this, discerning in the middle ages the cradle of our modern languages and literatures. Now, after having sought out, scrutinized scientifically and published most of the extant material in the vernacular languages, they are, I am glad to say, beginning to turn to the richer medieval literature in Latin and are organizing for its systematic exploitation. Students of economic history are pointing out such facts as that the same English towns which were prosperous and prominent in the thirteenth century came to life again only in the nineteenth century. Similarly representative government, found all over Europe in the thirteenth century, was thereafter gradually suppressed by kings until it revived again in the last century. In science and learning there has been no such setback as that, and no one must expect to find a startling likeness between the science of the thirteenth and the science of the nineteenth centuries, because other centuries of scientific progress have intervened between them. It is also true that in western Europe the very earliest medieval centuries seem a time of retardation in scientific development analogous to the depression which has prevailed in architecture and sculpture since, say, the seventeenth century. But the remainder of the medieval period has abundant extant materials for the history of science, more so probably than for any other side of human life except religion and perhaps art. The works can be more accurately dated and the relations between different authors traced more clearly than in the age of Greece and Rome. Various scholars have begun to publish and edit portions of this hitherto too neglected material, and the further study of it should greatly illuminate the process of human

thought in general and the development of modern science in particular. There is much magic and superstition intermingled with this medieval science—as, for that matter, there was with ancient science. This we must study, too, if we wish at all completely to comprehend the evolution of human thought and of modern science.

Evolution and the History of Science

You scientists, who accept the theory of evolution, who not merely experiment in the present but study fossils and the bones of extinct animals, who trace geological formation far, far beyond the first vestiges of human history and thought or even life, who perhaps experiment with the most primitive and elementary forms of life in order to understand the highest forms, who have abandoned the belief in permanence of species, who have tracked the sources of the most complex organisms back to the simple single cell and find there, perhaps, determinants of all the long-drawn-out later developments—you scientists, I say, can surely comprehend not the mere value but the pressing necessity for tracing the history and evolution of science itself, and for tracing it far, far back of the nineteenth century or Newton or Galileo or the invention of printing, for investigating it not merely in the recent butterfly stage of modern science, not merely in the larval stage of Greek thought, but also in the pupa of the so-called middle ages, and in the egg, it may be, of primitive folk-lore. You will not hesitate to commend the study of that other and seemingly earlier species of human thought, the superstitious and magical, with which science was for a long time at least closely related, if it did not indeed evolve from it. You will no more scorn the earliest crudest effort at experimentation, the first childish curiosity concerning nature, the first fantastic superstitious attempts to control nature than you would scorn embryology, the cell doctrine, and the investigation of planarians. It may not be such a far cry after all from such a treatise as the supposititious "Secrets of Women" of Albertus Magnus to recent theories of sex determination.

The Past Was Not Romantic and Unnatural

As you undertake to explain all past geological change by processes which can still be observed to-day, so you will expect to find the human mind developing slowly but steadily and scientific progress occurring step by step. But you will be suspicious of any historian who represents the past as romantic and unnatural; full, for instance, of inquisitors with thumbscrews, of imprisoned scientists writing in complicated ciphers, or of marvelously cultured Arabs, although their immediate ancestors were illiterate nomads and their present progeny are blind to the benefits of

British rule in Mesopotamia. What was the true state of affairs? Something nearer to this: even theologians obsessed by scientific curiosity, writing mathematical treatises, and performing natural experiments; even writers of the cryptic and occult recognizing the ascendancy of science; and far more scientific manuscripts in medieval Latin extant from little western Christian Europe than in Arabic from all the vast expanse of Moslem rule from Spain to India and Madagascar. When Pliny the Elder called his combined conspectus of ancient science and natural magic and record of civilization "Natural History," he chose a good title. May we investigate both nature and civilization as he did; and not only may our science be "organized common sense," but our history of science be scientific and natural and free from that credulous, fantastic, exaggerated and romantic strain, from which Pliny, try as he might, was unable to purge his book and his thought.

THE OLD WORLD IN THE NEW

By Professor EUGENE VAN CLEEF
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THE production of food in New England is not adequate to the needs of the people. Nearly 80 per cent. of the food consumed is brought from points outside the region. This means a constant high living cost. If one urges the New Englanders to consider the possibility of producing more food they respond rather complacently to the effect that all of the desirable lands are now under cultivation, and hence no material increase in the local production is possible. Yet, while they say "it can't be done," a new Pilgrim arrives and points the way. It is the Finn, as resolute and zealous an immigrant as has ever come to America, who has solved the problem of the better cultivation of New England soils and consequent increase in food production. The native people of this northeastern corner of the United States, as well as those in many other parts of the country, have an opportunity not only to increase their food resources, but to increase the value of their lands and return profits to themselves, if they will but heed the Finn, who has demonstrated his efficiency and stands ready to serve further.

Although the Finn came to Boston as early as 1860, his presence has not attracted much attention, for his coming has never been in consignments, by boatloads, or in terms of "immigrant movables." Industrial agencies have had no hand in bringing Finns to America. The earliest Finns were sailors, impressed by the possibility of earning a living more easily in America than in the home land, where they suffered from the oppression of a Russian autocracy. To-day they determine their own destinies, for in 1917 Finland declared herself a republic and was first recognized as such by the United States.

These sailor pioneers met with success at once and wrote their friends or in some instances ventured back to Finland to tell their friends and relatives of the economic opportunity awaiting them across the seas. As the years rolled by the Finns came in greater numbers, although at no one time in large numbers. The migratory process has always gone on quietly. Not all the Finns landed at the port of Boston, some having reached New England by way

of New York City, and scattered throughout New England. The earliest immigrants found their way out of Boston first to Cape Ann, where they were given steady employment in the granite quarries. Later, the quarries of Quincy and Fitchburg attracted many, while the lumber industry in other parts of New England lured some. After a while the Finns turned to the textile mills, chair factories and other industries which offered immediate work and quick cash returns. The Finn pays his way from the outset and avoids the stigma of becoming a public charge; hence his readiness to adapt himself quickly, even though temporarily, to any sort of work which will enable him to support himself until such time as he can better his condition.

The Finn is thrifty and independent. Both of these qualities are the consequence of his life upon the farm in his native country where isolation and the struggle against the odds of nature challenge the strongest and bravest of men. He has consequently developed a penchant for work, a tenacity of purpose and a skill in farm management which may well be the envy of the peer of America's best farmers. His objective in America is not residence in the industrial center, where the permanence of home is not all too certain, but rather upon the land, where his future is entirely a factor of his own direction and where he may commune with nature. Furthermore, the New England environment reminds him of Finland. Its glacial lakes, its boulder-strewn surface, its numerous elongate hills, its woods of graceful white-barked birches or stately spired evergreens and the deep winter snows "are just like home." The urge, in this environment, to do what he did at home, but under a political régime offering him freedom of thought and action, is too strong to resist and at the first opportunity he turns to the land.

Managers of industrial plants loathe to see the Finns move landward. They commend them as among their best workers and not infrequently make part-time arrangements which permit them during the early development of their farms to spend a portion of their time in the factory. Such an arrangement is mutually advantageous, for while giving the employer the benefit of Finnish labor it enables the Finns to secure some ready cash so essential while waiting for the first crop to mature. The Finn's mechanical skill has evolved for much the same reason as did that of the Yankee farmer of fifty years ago. The isolated farmer can not call in a plumber, a carpenter, a blacksmith or other specialist, but must be Jack-of-all-trades. So it is, that when the Finn enters a factory without previous experience in the particular industry, "he learns quickly." He soon becomes expert. He thereby de-

velops a double value to the community, on the one hand as an efficient factory employee, oftentimes excelling all other nationalities, and on the other hand as a superior tiller of the soil.

The Finns of New England have centered principally in Gardner, Fitchburg, Worcester, Maynard, the suburbs of Boston, in Quincy and in the Cape Ann district. Smaller numbers live in Peabody, Norwood and the vicinity of Cape Cod. Altogether there are approximately 35,000, including native and foreign born, in the State of Massachusetts, with a scattering in Vermont, New Hampshire and Maine. Throughout this area there are many "run-down" farms. Some of them have not been under cultivation for the last five to fifteen years. Outside of New England such farms have been known as "abandoned," but the New Englander says there is no such farm in his part of the world. It perhaps is not worth while to split hairs with him on the difference between a run-down and an abandoned farm. The fact remains that these farms have been in a state of abandoned cultivation because the struggle has been too severe for the Yankee farmer or he has not been able to solve the problem of how to farm these particular pieces of land. Now enters the Finn, who boldly, slowly, methodically and laboriously begins to rehabilitate these farms and to succeed where his predecessors have failed. He purchases a cow, some chickens and a horse, if funds permit. The first two items give him a substantial food supply in the form of milk, butter, eggs and even chicken-meat occasionally, while the third offers power and transportation. He clears a few of the almost innumerable boulders, cuts off a portion of the dense second growth vegetation to make room for hay and enough of truck garden products for his own use, and drains a portion of the land. Tree stumps give him no particular concern at first, for he just cultivates around the stumps. In the course of time, and for the Finn time accomplishes much, all the land will be cleared, drained and under the plow.

The first year of farming passes, the second year rolls by, a third year eventually terminates and yet much remains to be done. Is the Finn discouraged? Not at all, for he has vision and patience; he is encouraged by what has already been accomplished and knows that constant labor for a few more years will bring the realization of his dreams. The end of the fifth year, the seventh year and even the tenth year mark his successive goals.

In the vicinity of Gardner and Fitchburg, where ten or fifteen years ago Finnish farmers were a rarity, to-day they supply a very considerable portion of the citizenry of Worcester county with vegetables, small fruits and milk. In the spring of 1922 nearly

100 Finnish farmers marketed not quite 100,000 quarts of strawberries. This is a record commanding the careful consideration of every native New Englander. It is a record established upon those run-down farms and also, in part, upon new lands which the farm bureaus of the state tell us are profitable only for the growth of pine. The Finn is applying the experiences of his home land plus certain remarkable qualities evolved through many generations of ancestors. He knows how to solve just such problems as the lands of Massachusetts present and is demonstrating without the peradventure of a doubt that what the New Englander says can not be done, agriculturally, can be done. The Finn is a new Pilgrim come to New England to play a new rôle. He is increasing land values, increasing the food supply, and establishing permanent homes where the best of citizenship develops. He is doing all this with essentially no encouragement from the great Commonwealth of Massachusetts and in the face of much discouragement.

A few people say the Finn is a radical and hence not desirable in America. They justify their attitude toward him upon these grounds. A sweeping indictment of this sort deserves investigation. Our lack of a scientific attitude of mind toward the immigrant problem is fraught with much danger. New England's unwholesome caste-system atmosphere serves but to stay the wheels of progress. Here is an opportunity for gain to New England and America, yet because of the absence of scientific methods which would lead us to a correct understanding of a people otherwise strange to us, we automatically encourage discontent and social unrest. What are the facts relative to the Finns?

About 40 per cent. of the Finns are Socialists and a fractional portion of one per cent. of this group is actually radical. Neither the Socialists nor radicals dominate Finnish life, although the latter cause all the trouble which has brought the whole people in some instances into unfair ill-repute. Clearly it is not right to judge the majority action by the behavior of an insignificant radical minority. It would be just as unfair to say that all Americans whose ancestors came over in the Mayflower are thieves just because a few now and then are caught stealing.

The Finn's radicalism is not all of his own making. Seemingly, only the I. W. W. organization has concerned itself seriously with the Finn and to the credit of the Finn, be it said, very few have joined its ranks. If we Americans would put forth an equal effort to interest the immigrant Finns in our institutions there is no question but that radicalism would be an unknown factor among them. The social worker needs to study the historical, political, geographical and anthropological background of the newcomer and approach

him accordingly instead of trying to teach all immigrants by the same formula.

The Finns have an oriental ancestry modified by a few hundred years' residence in Europe. Good evidence shows that they migrated from central Asia, the region of the Altai Mountains. One group upon reaching the Volga River moved up that greatest of Russian arteries and thence into northern Finland. Another group crossed the lower Volga, proceeded across southern Russia, skirted the north slopes of the Carpathians, thence northward to Esthonia and across the Gulf of Finland into the land of the present republic. The modern Finns have lost much of their orientalism, yet retain enough to enable even the casual observer to appreciate it. Those of northern Finland, especially, show the broad head of the Mongolian with slant eyes, high cheek-bones and square-set jaws. The language is unrelated to any other European tongue excepting that of the Magyars, and then only to the extent of perhaps a dozen words. The Finnish mind moves slowly, cautiously and deliberately. The Finn listens to argument but reaches conclusions at his own leisure. He is not to be hurried; he is phlegmatic; he is thorough. During long residence in Europe the Finns have come successively under Swedish and Russian rule, and in their trade with the world they have felt German, English and some French influence. With this sort of background how could any one believe that the Finn can be approached in the same manner as the German, Italian, Russian Jew or Greek and be met with any degree of success.

The Finn is suspicious, self-reliant and independent—characteristics resulting from isolation upon the farm where he knew not whether the approaching party was friend or foe. He seeks no help and he takes his reverses philosophically. Charity is repulsive to him and patronage meets with resentment.

Employers in the large industrial plants say that the Finn is uncomplaining. They wish he were not so, for occasionally they do him an injustice. He accepts their verdicts without argument and seeks other fields to conquer. This characteristic certainly operates to the Finn's disadvantage, for when he is dissatisfied with working conditions he simply quits the job, whereas a complaint registered or suggestion offered might readily result in improved conditions. A neat case in point is that of the experience of an employment manager in a factory where upwards of 5,000 men are employed, some 400 or 500 of whom are Finns. In certain of the manufacturing processes the workman is exposed to continuous high temperatures. The foreman was impressed by the fact that when the Finns were put on this job they remained only a

few weeks. They quit because of the heat. On the other hand Italians doing the same work were permanent. But the latter were not as efficient as the Finns because of their lack of sufficient muscular power. By arranging the work of the Finn so that he might have relief from the heat several times during the day he could be retained for months and in some instances a few years. The Finns might have told their foreman in the first place why they would not remain at this work and profited accordingly; on the other hand the employment manager demonstrated what could be accomplished with the immigrant by scientific observation.

Some New Englanders protest that the Finn is unappreciative of the efforts made in his behalf and to prove the correctness of their assertions they point to the fact that when brought together in class groups to receive instruction in Americanism they refuse to sing "America" or the "Star-Spangled Banner."

Analysis reveals the absurdity of the methods of some of the so-called Americanizers in their Americanization work. A direct appeal from a clear sky will not reach the Finn, even though it gets response from other nationalities. Yet this is exactly what has often been tried and found wanting. As previously stated, the Finn is suspicious; he must be convinced of your sincerity and purpose. He is best approached through one of his own people. Hence by gaining the confidence of one of his number, and then through him or with him presenting the appeal, results come forth in rapid succession. Then the Finn sings "America," the "Star-Spangled Banner" and even "My Old Kentucky Home" with all the gusto of the most ardent American citizen. He will do even better than that as witnessed by the writer. He not only will sing "America" in English but will follow at once with the Finnish translation, thus assuring a doubly good job of it.

New Englanders should congratulate themselves that among the numerous nationalities living upon American soil, one at least represents the regeneration of the Pilgrim spirit. The few radicals can be readily eliminated by encouraging them to farm the land, or by carefully and intelligently working with them in other directions, but not by antagonizing them. Many a "Red" has become true blue after acquiring some land and a permanent home. The great mass of Finns give no trouble, but on the contrary are notable for their quiet and modest ways.

What they have accomplished has come about in spite of discouragements. The opportunity to capitalize a new people, if capitalize we must, was never greater than is afforded the people of New England to-day. The responsibility for the right development

of the Finns into a splendid citizenry rests not with them but with the native stock, for they have already shown their metal. Will those who pride themselves in their American ancestry live up to the traditions of their forefathers and lend not a helping hand but a cooperating hand to a worthy people from whom they may actually gain, or will they permit the battleground for American liberty to serve as the site for the development of a social unrest?

BASES OF BRYANISM

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THE attention which Mr. Bryan's latest interpretation of the popular mind has attracted from a group of theologians and scholars who are not wont seriously to notice such productions seems to justify two observations. The first indication is that a belated recognition has come (1) of the lamentably great hiatus that has long existed and has been also long widening between men of science and the unlearned multitude who ultimately, even if unconsciously or involuntarily, support the researches that taken together constitute scholarship and (2) of the retardation of research of every kind by the stealthy pressure of an unsympathetic social milieu. Without asserting that the popular mind stands still, one will not, however, miss the truth far in declaring that every advance by men of learning over the religious and political philosophy of the Revolutionary Fathers has widened the breach between the many who support and the few who promote science—so slow is the task of raising the general level of intelligence. One does not have to fall back purely upon the authority of adages to justify a solicitude for the future of a house thus divided against itself. It is a commonplace to thought that research, of any kind whatsoever, can not fulfill its high mission in a democratic society without a growingly large, even if somewhat dumb, popular approval: without this large ground swell in its direction, research tends either to decline or to become so detached from the common life and aspiration that give it its genesis and justification as to menace while it does persist rather than serve as the organ for popular liberty. For to science also, in the long run, applies the picturesque motto of the French politician, "Walk from the people and you walk into night."

The second observation that seems justified is that Mr. Bryan speaks not for himself alone: he remains what he has for so long been, both the interpreter and the prophet of a great mass of men whose political and religious aspirations find no more commanding articulation. Addressing himself to "the heart and mind of the average man," Bryan speaks for, as well as to, a substantial group of sturdy Americans. Indeed, so far ahead of most public men is Mr. Bryan in responsiveness to popular feeling that one

might suspect that while others still depend upon the old-fashioned and uncertain method of keeping an ear to the ground, Mr. Bryan walks in the garden of human nature in the cool of the day, like the God whose cause he pleads, and by an invisible radio extracts from the twilight zephyrs precisely what common men think and feel. It is this representative capacity of the man that all critics and reviewers perceive and justly emphasize. There is no occasion to exaggerate either the size or the influence of his constituency. It is indeed altogether probable that even as a religious prophet—as a politician he has, you remember, been dead or dying these many years!—he speaks to and for a constantly declining number of people. But that is not to say that he is a voice crying in the wilderness. Throughout much of the west and most of the south—where, be it remembered, there live millions of Americans who still bear children, vote at election time and determine the level of whole systems of education from the common school to the state university—Bryan is read, heard and revered. It is not uncommon in homes where books are numbered by one-and-one rather than by shelves and cases to find Bryan bearing sacrosanct testimony to the inherited elemental philosophy upon which both popular religion and popular politics rest. On a certain modest stock farm in the southwest I recently found shortly after it was issued Bryan's "In His Image," and was cautioned by the owner by all means to read it. This same man, who both in his sturdiness of character and his inherited idea-system represents the pyramid of American society at its agricultural base, had years ago bought and read Bryan's first book of campaign speeches when there was in his home hardly more than one other book, the Bible. And yet he has never shared either the specific religious or political affiliations of Mr. Bryan. Such test cases are at any rate numerous enough to make an analysis of Mr. Bryan's faith an essay in the motivation, the belief and the action of the common man. The growing recognition of the importance for the scientific technician and for the future of science itself of the attitudes of this same common man justifies a more careful analysis of the bases of Mr. Bryan's philosophy of life, that is to say of his religious philosophy, than has yet appeared.

II

A reflective consideration of the implications of Bryan's James Sprunt Lectures, entitled "In His Image," will disclose at least three large assumptions that serve as bases for the arguments: (1) a distrust of human nature *überhaupt,* (2) an undisguised emphasis upon human feelings as over against reflection, and (3) an extravagant optimism based upon factors confessedly outside of

human control. Unless these assumptions be considered, the premises of popular arguments may be refuted *seriatim* without seriously interfering with the functioning of the conclusions. Like the hero of a once popular ballad who, when his legs were shot away, fought still upon the stumps, Bryan's arguments bear, too, a charmed life. Really to refute them one must change the over-beliefs from which they secretly draw their vitality; and to chance these conditioning beliefs one must change the basic action-patterns of men, a change that is often best accomplished by, and sometimes only by, a change in occupation. Let us carefully examine this threefold basis.

To assert that Mr. Bryan lacks confidence in human nature and that moreover he capitalizes this distrust as a foundation for his major arguments may seem unnecessarily to fly into the face of patent facts. For Mr. Bryan not only consistently avows a robust confidence in human nature in general but, what is more, in those very representatives of human nature that to most critics seem least promising, *i. e.*, in common men. He surrenders first place to none in his belief that "mankind deserves to be trusted." It is to this "average man" that he addresses his arguments; and it is from this same man that Bryan draws inspiration and courage by which his position is fortified; for the position that he attacks is, as he says, "so unreasonable that the masses have never accepted it." But one who knows Mr. Bryan will not by any such asseverations as the foregoing be misled as to Bryan's real appraisal of human nature. Mr. Bryan's trust waxes great only in small matters: before questions of "eternal" import man's greatest wisdom is utter folly. And such questions are never further away from Mr. Bryan's ratiocination than the back of his head: every spoke of a wheel has a way of ending in the hub. It must never be forgotten that Mr. Bryan is still preoccupied with the soul and its salvation, that his cosmology is of the two-world variety and that the "other" world is transcendently more important in proportion to its invisibility.

Now the important thing about this medieval dualism is the psycho-ethical implications of it. A certain theory of human nature alone is compatible with this inherited view of the world—the theory that human kind is naturally depraved. As once stated, the theory humbled man to the level of one who could not think a good thought nor do a good deed. But even Mr. Bryan would no doubt slightly modify that statement of the theory, though the theory itself he does not renounce. Indeed, he is convinced that "no one will doubt the doctrine of original sin if he will study nature and then analyze himself." This view of human nature involves as an imperative condition for wise living and right think-

ing an alien standard furnished as a supplement to native human capacity. Human autonomy gives place to a religious autocracy. Of course, this dualism, once introduced, logically involves the necessity of a medium of interpretation as authoritative as the original standard, unless the benefit that motivates the theory is to be sacrificed. It is precisely because of the logical impossibility of making an infallible standard available as guidance for fallible men, without some loss of infallibility, that churchmen more enlightened than Mr. Bryan have been obliged to give up this entire medieval inheritance. But Mr. Bryan wars upon his more intelligent brethren purely because the logical difficulty which they have honestly faced is too profound to catch his attention. There is, however, personal extenuation in the fact that Mr. Bryan has long specialized, not in logic, but in oratory. It is precisely because of this radical distrust of human nature that Mr. Bryan lays hold with such an unrelinquishing hand upon divine aids. And once seized, they are to be trusted all the way. "Bible characters grappled with every problem that confronts mankind, from the creation of the world to eternal life beyond the tomb. They gave us a diagram of man's existence from the cradle to the grave and set up warning signs at every dangerous point."

The chief cornerstone of Bryan's philosophy is thus laid in the Hebrew maxim that "it is not in man that walketh to direct his steps." If this is not giving a dog a bad name in order to hang him, it is at least attributing to human nature such a constitution as without further ado necessitates the ministration of the traditional deity. Man's extremity is made, as always, the theologian's opportunity; and no time is lost in capitalizing this human extremity to justify the foisting upon man of a fundamental and thoroughgoing religious authoritarianism. This is a strange doctrine to be enunciated in a democracy by a leading democrat. All philosophers of democracy since de Tocqueville have noted the incompatibility between democracy and any extraneous authority. Mr. Bryan himself is not without a certain vague feeling for this incompatibility. To compensate for the great discrepancy between his religious philosophy of dominance, which is held to be fundamental, and his democratic political philosophy, Mr. Bryan compartmentizes human nature and then finds—such is the deviousness of rationalizing!—that the doctrine of original sin applies less to one department of human nature than to another. While on the whole, man will certainly not do to trust in fundamentals, yet if one can find the right spot in man's nature, he is not so bad after all. And this moral oasis in the desert of corrupt human nature is the heart of man. So much better is the heart than the head, according to Mr. Bryan, that one might be led to conclude that

Eve ate the fatal apple, not because her heart was set upon it, but because she syllogized herself into its acceptance. Indeed, he does not omit to say that "the conflict that rages between the mind and the heart is the one great conflict in every life. Reason vs. faith is the great issue to-day as in Eden. Faith says obey; reason asks, Why?" Thus Bryan leaves no doubt as to which is the Lord's side in this eternal conflict between the mind and the heart. "The heart of mankind is sound;" but "the mind is a machine; it has no morals." And so, as might be expected, "the Bible's proof of God becomes increasingly necessary to meet the agnosticism and atheism that are the outgrowth of modern mind-worship." Let it be made plain once for all that Mr. Bryan wars on agnosticism, atheism, even evolution only incidentally. These are but the foliage; he strikes at the root, and the root of all modern evil is the too high appraisal set upon mind. His quarrel with Darwinianism is motivated here; for, as he declares, "the natural and inevitable tendency of Darwinianism is to exalt the mind at the expense of the heart." "Religion is a matter of the heart, and the impulses of the heart often seem foolish to the mind." "Hearts understand each other." And finally he summarizes in a burst of oratory: "I fear the plutocracy of wealth; I respect the aristocracy of learning; but I thank God for the democracy of the heart. It is upon the heart level that we meet, it is by the characteristics of the heart that we best know and best remember each other."

This superior excellence of the heart presumably consists in the fact that the heart is more amenable to authority than is the mind. Its merit, like that of women under the same philosophy, consists in its docility. As Bryan says, "When we deal with the heart we deal with religion, for religion controls the heart." Ignoring the question as to whether this is a true description of man's emotional as over against his intellectual nature, it seems certain that this explicit bias in favor of the emotional element is one of the strongest bonds of kinship between Bryan and the common man for whom he speaks. Thinking is hard work; verily there is no pain like the pain of a new idea, especially if it be a religious one. Moreover, thinking arises from uncertainty and doubt, and uncertainty is not a satisfactory emotional state in which to be. It seems perfectly clear that Mr. Bryan's aversion to change is motivated in this reluctance to endure the pain of thinking. He is so quick to scent in the air any maturing demand for change that even the evolutionists can not fool him. Brightly detecting the implications of their doings, he declares that "while the process of change implied in evolution is covered up in endless eons of time it is change nevertheless." Turning, however, in the same sentence to the brighter side, he finds comfort in a biblical

statement that, as he assures us, "does not leave any room for the changes however gradual or imperceptible that are necessary to support the evolutionary hypothesis." "Books on biology," as he elsewhere solemnly declares, "change constantly, likewise books on psychology, and yet they are held before the students as better authority than the unchanging word of God." Recoiling thus from the bared "tooth of time," Mr. Bryan glorifies changelessness, as if an unchanging law could be either permanently true or just in a changing world! The way to easy victory over this shamefully transitory world becomes the possession of a strong faith motivated by unquestioned desire; and the criterion for any doctrine comes to be the ease with which it may be believed. This criterion Mr. Bryan explicitly sets forth in the remark that he knows of "no theory suggested as a substitute for the Bible theory that is as rational and as easy to believe." Since ease is for the most part a matter of wont, it is clear that true ideas turn out to be the old ones, and false ideas, new ones. Of ideas, as well as of men, Dr. Johnson spoke with insight, then, in declaring that "all foreigners are fools." And Mr. Bryan does not hesitate elsewhere explicitly to avow that credence and loyalty are due a hoary theory of man's origin as over against a modern scientific account. At the bottom of all this is the simple understandable fact that belief follows desire, follows it the more naïvely and pantingly the more untrained the believer. In spite of the fact that many human desires are frustrated completely and the majority of human desires partially, the existence of strong desires is still considered in Mr. Bryan's theology as of indubitable ontological significance.

It is because desires are taken as self-guaranteeing that common sense, speaking through Mr. Bryan, is extravagantly optimistic about the goal of humanity while being distrustful of human nature itself. Human desire is but an arrow pointing out the direction of the fruition that God will provide. There is truth in this conception but common sense insists upon such a bizarre form of conceiving it as to belie its nature. Extravagant desires are born of abnormally harsh circumstances; the circumstances that make possible the religious desires of common men create also the machinery—gods, theologies, theodicies—to make certain their ultimate satisfaction. Of course the beggars will all ride so long as wishes are horses. There is nothing to be wondered at in this, but there is much to give pause to men of science.

For the simple truth is—so plain that even he who runs may read—that common sense puts its trust in the irrational only because and only so far as the rational has failed it. Where control has been achieved by, or furnished to, the common man, he no

longer relies upon the occult. But where he knows not what to trust, he trusts he knows not what. Where the telephone reaches, the common man depends no longer either upon prayer or telepathy for communication with his loved ones; he telephones. In illness, a cure is ordinarily credited to the doctor; a death, to God. And so throughout: where control is furnished, control is used. The farmer and the unskilled laborer trust the occult and lean heavily upon compensating desires of future rewards; the skilled worker in industry trusts his union. The religious philosophy of the former is no more to be marveled at, and no less so, than the developing irreligious philosophy of the latter. The boundaries of control mark the boundaries of the average man's trust in human nature. Where control stops, distrust of human nature and an extravagant optimism born of reliance upon the boundless irrational sets in as compensation. Being somewhat scantily equipped with such knowledge as enables him to control the real world (evaluate his secretaryship of state in the light of Ambassador Page's letters), Mr. Bryan simply dissipates in the ideal, as may be seen alike in his conception of the destiny that awaits "our ideal republic" and in his conception of the heaven that is to end the career of the saintly man. And as acts Mr. Bryan, so acts the average man. Confidence in rationality can not far outrun the achievements of rationality among those of little imagination. And while there is political control, the common man is not to any large extent in on it. He replies by distrusting human government as a necessary evil and sometimes by refusing to contaminate himself by even so much as voting. Here Mr. Bryan has gone somewhat ahead of the common man, and by so much as he has gone ahead in getting in on the political control that is actually exercised, by so much has his confidence in the ability of men to govern themselves run ahead of that felt by the average man. It is perhaps not without significance that Mr. Bryan's zealous preoccupation with superearthly means of control has grown greater as his influence over his party has declined. But even in the days of his greatest influence the boundary line of Bryan's control stopped at "Wall Street," and so there he builded his bugaboo, the same sort of bugaboo that the average man has builded back at the ballot box. For, as forts mark the boundary line of national control, so do bugaboos mark the boundaries of human control: where light ends, darkness sets in.

III

All this but means that Mr. Bryan has stated in terms of modern relevancy the never-dying challenge to intelligence. What seems to be a complaint at modern theories can most profitably be

interpreted as a wail from inarticulate men that they have not been let in on modern advances. And to this complaint, so interpreted, science can not reply that it is making available labor-saving machines and other devices as fast as they can be perfected. The gift without the giver is bare. Average men must be increasingly let in on the processes that lead to inventions, on the theories of life and the hypotheses of progress, if the products are not to cease. As simple and as convincing as are the elementary observations on which Darwin based his evolutionary philosophy of life—conquering thus, as Dewey so well puts it, "the phenomena of life for the principle of transition"—more than half a century after the general acceptance of this philosophy by men of science the average man remains utterly ignorant of the evidence that has convinced all who have examined it fully. The average man expresses all he knows about evolution in his retort that *you* may claim the monkey for an ancestor if you wish, but as for him, he prefers another line of descent. So aristocratic is the pedigree of the professions that most professional men actually seem to prefer to confer benefits without divulging knowledge of the means by which they come. The average man takes a tonsilectomy or an operation for appendicitis without softening in the least his opposition to evolution! Indeed many a doctor, instead of conceiving himself as an educator, apparently regards himself as having the valuable key to a kind of esoteric knowledge. The customary reticence of medical practitioners is more befitting the magic past of medicine than its high mission in a democracy. In the face of such neglected opportunities, science cannot reply that she is willing to give, but that the common man is not ready to receive enlightenment. Science must take up the double burden of intelligence, not only to sow the seed, but to prepare the ground as well; not only to give, but to reconcile the receiver to the gift. Whatever is not worthy to share is not worthy to hold. We do not sympathize with a "great" artist who can not get audiences. On the contrary, we charge the artist with the double responsibility of creating both his art and his audience. And the scientist can expect no easier berth. Indeed, he must perhaps reconcile himself to a more difficult mission; for in his case there is perchance a greater readiness to accept the holy fires which he steals from the altars and yet to anathematize the altars that produced them. Insofar as this is true, if true, the scientist may compliment himself on having the bigger job. But there is no shirking it. The altar belongs to its fires, even as do its fires belong to the people.

This point will bear emphasis without becoming labored. Science can not reach its goal separated from the people, and yet

science is separated from the people. If one would see how widely, let him turn round and look at the shadows on the wall cast by the passing panorama. Mr. Bryan's dualistic psychology is the reflection: the heart and the head are at outs, and Mr. Bryan allies himself with the heart, as if the heart could arrive without the head! But Mr. Bryan chooses sides because he finds there are two sides and a battle is raging. He chooses the heart because somebody before him has chosen the head, as if the head could arrive without the heart! A dualistic psychology, as well as a dualistic cosmology, reflects a schism in humanity, a deplorable schism which it is the task of wise men to heal. This burden falls primarily upon the scientists, not only because they are the ones who are responsible for it and because they are the only ones who are able to bear the burden, but because also, insofar as only one side can be in the right, the common man is in the right. The emotional life of man *is primary.* Both phylogenetically and ontogenetically the human "heart" has the right-of-way. "All thought," as James Russell Lowell truly observed, "begins in feeling." But the error of the average man consists in wishing to run amuck because he is granted a right to run freely. Since humanity finds itself possessed with intelligence as an effective instrument for the safety and enrichment of its emotional life, the common man must be prevailed upon not to discard what mankind has so hardly won and so badly needs. Science must humbly reinstate itself as the instrument of humanity's desires—

> That mind and soul, according well,
> May make one music as before,
> But vaster.

The needs of humanity render this no more imperative than does the perpetuation of science itself. And since intelligence does exist as the instrument of human need, intelligence must save its life by losing its pride. The impasse in which all such argument seems to end ought to become a standing challenge to wise men; for if science can not live with the average man, it certainly can not live without him. This is the dilemma that betokens social progress, for in its resolution the average man ceases to be the common man.

THE PLACE OF THE SYSTEMATIST IN MODERN BIOLOGY

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IT is related in the Book of Genesis that all the animals were caused to pass before Adam and Eve and that our progenitors gave to them names. Relatively speaking, it has not been so very long since biology has emerged from what we might speak of as this Adamic period, the period in which the chief, if not the only, interest of the naturalist was to give names to as many as possible of the animals and plants that he had seen, or of which, perhaps, he had only heard. When an organism had been provided with a scientific name accompanied by a few words in Latin that purported to be a description of its chief characteristics it was labeled as "known." And even to-day a very large proportion of our animals and plants are "known" only in this way.

Now, after all, naïve as this may seem, it is not so very different from what we find in other fields of scientific endeavor. The belief that when we have once given a thing or a phenomenon a name we have gone far toward understanding it has not yet been relegated to the limbo of such other superstitions as a belief in the efficacy of charms and the influence of the moon on the growth of potatoes. Men still—at least some of them do—speak glibly of enzymes and vitamins and tropisms and other phenomena as if, now that they have names, we really know what they are and not merely how they behave. A salmon swims upstream to spawn because it is positively rheotropic—a sufficient explanation!

Nor can it be denied that in this mere naming and describing of species there was much of value. Through it men came to know of the richness and diversity of life. Through it we have been made aware of many of the facts that have led to the attempts to explain the origin of species. It has furnished us with the background from which our modern biology has emerged. Yet this naming and arranging of species is not now and for many years has not been the chief end and aim of biology. Morphology, embryology, cytology, physiology, genetics, biochemistry, each in its turn has entered the field and for a period has held its place in the spotlight of interest. Systematic biology has been pushed farther and farther to the side until it has come to occupy but a minor

place in progressive biology. In fact, there are those who would say—and do say—that it is no longer worthy of the serious attention of any one who aspires to the dignity of being called a scientist. Its day is past. It no longer has anything to give us. It is a task merely for the cataloguer, for the individual who, perhaps because he is incompetent to do anything else, spends his time poring over musty volumes and digging up long forgotten names with which to confuse the worker in other fields.

Now I profess to be a systematist—in other words, my chief interest in biology happens to be centered about the task of trying to find out how many and how various are the species of certain groups of insects, of attempting so to describe and figure these insects that others may be able to determine whether they too are dealing with the same species, of so arranging these species in groups of varying rank as to indicate their probable degrees of natural relationship. Incidentally the giving of names to those species that do not now have them is involved, as is occasionally the changing of names already given. In the light of the opinion of the systematist that is sometimes voiced, how am I to justify myself for spending my time in such a task when the whole great field of genetics, let us say, lies open before me? How am I to maintain that faith in the value and dignity of my work that is necessary to the peace of mind of any conscientious laborer?

A very simple answer and one that generally satisfies me, at least, is merely that I like to do these things and that I care not a single good loud whoop whether any one else approves of it or not.

But such an answer is not likely to convince a sceptic of the reasonableness of my position—and I must admit that there are times when it is not sufficient to convince myself. I must occasionally stop and inquire into the basis of my faith. There follows the argument with which I succeed in convincing myself that my work is not wasted.

First, let us consider what systematic biology is not.

It is most emphatically not the poring over of musty volumes and the resurrecting of old names that some—unfortunately some systematists—seem to think. It is not merely an endless quibble over the rules that are to be followed or whether any are to be followed at all or whether this name is to be regarded as having been published within the technical meaning of the term or which name has priority over which or whatever it may be that systematists find to quarrel about. These are but side shows, although recalling a famous controversy that raged for months in one of our entomological periodicals, one might be tempted to remark that they are sometimes a circus in themselves.

These things are no more systematic biology than bookkeeping

is business. Bookkeeping is merely an indispensable adjunct of business and rules of nomenclature are merely a more or less indispensable aid in taxonomy. We may regard bookkeeping with impatience as did the country banker of whom this story is told. The bank examiner in going over his establishment found a drawer containing some cash of which there appeared to be no record. He inquired about it. "That," said the banker, "is my odds and evens drawer. When my books come out with too much money I put it in here and when they come out behind I take it out." Still, however impatient we may be with such small details, whatever our contempt for the bookkeeping type of mind that can not forget the odd cent even when dealing with sums amounting to millions, the fact remains that a certain degree of care in such details is highly desirable. These things are a part of the rules of the game and there are but few games that can be played entirely without rules.

Neither is systematic biology the mere giving of names to species "new to science." To be sure, that is a part of it, for even at this late date there are probably more organisms that do not have names than there are that have. Consequently, this discovery and naming of new species that have not been named is frequently necessary, for it is difficult to discuss things for which names are lacking. I would not deny that there is a certain amount of pleasure in thus bringing to the attention of the world something that no one has ever seen before, in holding up as it were the mangled remains of some almost invisible insect or microscopic plant as a justification for exclaiming, "See what I have found." There are, it is true, systematists who seem to look upon this as the end and aim of their work, like the young man who wrote to a professor of entomology saying that he had always wanted to describe some new species and asking if any were available that he might have. Yet we may dismiss these individuals, as the young man was dismissed, summarily and without regrets.

If these trivial things be not the aim of systematic biology, no more is its aim the grandiose one of solving the problems of the universe. At least I do not think there are many systematists who delude themselves into thinking that they are solving any such problems. Systematic biology can not explain the nature of life or of its processes. It can not explain how species originate or how they are perpetuated. It can not, at least as practiced by most systematists, explain even what a species is. If these things are to be explained at all it must be by some other method of approach, in the end, I suppose, by the methods of biochemistry.

What, then, is systematic biology? What can it do? What

significant contribution can it still make to the progress of biological understanding?

As I conceive it, it is a serious attempt to discover, to describe and to arrange the facts of nature that have to do with the number, the characters and the relationships of all those indefinable groups of individuals that we speak of as species and to present these facts in as clear, as definite and as understandable a manner as may be in order that they may become available to all students of biology in whatever field they may be engaged. It of necessity involves the study of morphology and anatomy. It may utilize the methods of the geneticist. It may call often upon the physiologist and even in extremity upon the chemist for aid in solving its problems. As thus defined it undoubtedly involves far more than many systematists will be prepared to admit, a fact that disturbs me not at all.

As an independent field of investigation it can throw much light on the question of what happens to species after they have once become established. The whole great series of problems involved in the question of geographical distribution with the attendant conclusions and speculations as to places of origin and roads of dispersal of species and larger groups is approachable only by the methods of the systematist. Paleontology is but little more than pure systematic biology, and whatever its contributions to scientific theory may be they are the contributions primarily of systematists. The ever-fascinating problems connected with the study of ancient man and of human origins are essentially nothing more than problems in systematic mammalogy. Whether the "Piltdown man" was a man or merely a chimpanzee, the place of the Trinil man in evolutionary theory, these are nothing more than problems of the systematist working as a physical anthropologist.

Aside from this independent field with its independent contributions to biological theory, systematic studies are the fundamental basis of practically all applied biology and of a large part of the remainder. Discrimination between species—this is the starting point of the majority of our problems in biology. The ignorance—or the ignoring—of this fact is sufficient to invalidate and has invalidated much biological work.

As an example of the effect of poor systematic work on biological theory let us consider the case of certain scale insects. It has been asserted that the females of a small group of species are seasonally dimorphic, and in an attempt to explain this supposed fact an author has advanced the theory that the dimorphism is due to retarded metabolism in the winter forms. No such assumption is necessary, for the plain fact is that the authors who were responsible for the statements concerning this dimorphism had simply failed to discriminate between two or even more species that

chanced to be feeding upon the same host plants. The work of a recent author who has dealt with the very interesting subject of caste formation in certain social insects is at least open to criticism and may even be quite invalidated by reason of a failure to recognize the fact that two closely related but nevertheless quite distinct species were present in the material examined.

In the practical field of economic biology we have even more striking examples of the necessity for care in the basic systematic work. Of three mosquitoes differing so little that the ordinary observer would scarcely distinguish them—they all bite with equal viciousness—one will transmit yellow fever, another will transmit malaria, and the third will be entirely harmless except for the transient pain of its bite. It is said that of perhaps a hundred species in the malaria-carrying mosquito genus *Anopheles* less than half are capable of transmitting the disease. And the habits of these species are as different as their potentialities in disease transmission. Yet the majority of these species are probably recognizable only by a specialist. The need of careful systematic work upon them should be obvious.

Of the hundreds of species of scale insects that are known, but a few are of any special economic importance. These few are in some cases scarcely distinguishable from others that are of no importance whatsoever and the specialist is constantly called upon to furnish the non-specialist with identifications of material.

A striking example of the importance of a systematic knowledge of insects has recently appeared. A weevil found on potatoes in the southern states was identified by the specialists of the Bureau of Entomology as a species that had evidently been introduced from South America. It was found further that it had also been introduced into Australia, where it had become a serious pest. With the knowledge of these facts we are at least forewarned as to what we may expect the insect to do in this country.

Especially in attempts to control insect pests by introducing their natural enemies is there a need for this kind of work. Most of our insect pests have been introduced from foreign countries and are pests here simply because they have left their natural enemies behind them. The problem of finding their natural enemies is first of all the problem of finding where the insects came from, and the answer to this depends upon the identifications of the systematists. Whether the insect that has been introduced is the same as one that occurs in Africa or whether it is one that is found only in Asia—upon the answer given by the systematists depends the direction in which the searchers for its natural enemies will go.

In parts of our western states the pocket gophers are a serious menace to crops. I am informed by one who has been engaged in the practical control of these rodents that it is first of all necessary to discriminate between the various species. Each species has its own peculiar habits, and the poisoned bait that is effective with one will fail entirely with another. So it is throughout the entire field of applied biology, the services of the systematist can not be dispensed with.

It is true that a very large amount of systematic work can not thus be correlated with any special problems of economic or philosophical importance. Yet because of this are we to say that such work must not be done? Who is to say just what work is likely to prove of value and what is not? Who would have thought that any practical benefit could ever come from a knowledge of the various species of sphagnum moss that occur in our peat bogs? Yet during the late war, when it was found that sphagnum moss could be used as a satisfactory base for wound dressings, this knowledge became necessary, for it was found that not all species of this moss were equally useful and a recognition of the species was essential to their proper utilization. I can not believe that apologies are necessary for studying any organism, however obscure it may seem.

On the other hand, there are certain valid reasons why the systematists may in some quarters be regarded with scorn. For one thing, it is a plain fact that much systematic work has been inexcusably bad, so poorly done indeed that it can not possibly be of use to any one. Nor does such an accusation apply merely to the work of the older authors. I have seen descriptions of recent date, in entomology and in botany, at least, that will not permit even an approximation to an identification of the species that they purport to describe. I have seen descriptions that violate every rule of ordinary common sense, and such descriptions are being published to-day in a certain field of entomology.

Another fertile source of distrust is to be found in the purely nomenclatorial wrangles and changes of which I have spoken. Undoubtedly in these there is often much that is trifling, much that is pedantry, much that is actually harmful. Yet here the case is by no means one-sided. A part of the fault certainly lies on the side of those who are not systematists and who have never troubled themselves to acquire the viewpoint of the systematists. To them a change of name is merely an annoyance, regardless of the reasons for making it. To them the splitting up of some long familiar genus with the accompanying changes in the names of well-known organisms is anathema. It matters not that this genus may have

stood so long simply because no one has ever taken the trouble to give it careful study. Progress in their own field is accepted without question, but progress in taxonomy with its inevitable changes is only to be fought. It is, I suspect, largely from this group that we hear so much of the return to Linnean genera, a phrase that—like the famous "self determination of nations"—will not bear close scrutiny.

Another difficulty is the fact that systematic biology, being perhaps the most primitive form, has always been especially favored by the amateur. Now there is nothing finer than the amateur spirit, and the loss of this spirit is much to be deplored. But although we may admire the enthusiasm that leads some utterly untrained worker, without access to literature and without a background of understanding, to plunge into some group, like the scale insects, that is sufficiently difficult even for the trained worker, we can not but shudder at the results. And there has been much of this sort of thing, especially in botany and entomology. It is unfortunate that the democracy of science should necessitate the giving of equal consideration to the work of the ignorant, the mentally unbalanced and the trained student. It is especially in the field of systematic biology that the evil effects of this are felt. The physiologist or the chemist, having demonstrated that a piece of work is valueless, may push it aside and forget it. By the very nature of things the systematist can not do this—the mistakes of the past remain a millstone about our necks. Some day we may find a way to relieve ourselves of them, but that time is not yet.

What is needed, then, is a realization on the part of the systematist that his work is not an end in itself, but that it is a part of the whole great field of biology, that what he does is of importance to the workers in other fields and that it should be done in such a way that it can be used by them. There is needed a constantly improving standard of work and a more keenly critical attitude toward all work that does not maintain the highest standards. And there is needed on the part of non-systematic workers a realization of the fact that they can not well dispense with the services of the systematist. There is needed a realization of the fact that the systematist is not of necessity and should not be a person of inferior capabilities. In fact, the economic worker should pray that the best minds that are available, except his own, shall busy themselves with the doing of the systematic work upon which he is dependent. We are all striving toward the same goal, a fuller understanding of the multitudinous facts of nature. The place of the systematist is that of a full partner in this striving.

THE CONSERVATION OF THE MARINE LIFE OF THE PACIFIC[1]

By Dr. BARTON WARREN EVERMANN
DIRECTOR OF THE MUSEUM OF THE CALIFORNIA ACADEMY OF SCIENCES AND OF THE STEINHART AQUARIUM

THE dependence of commerce upon science is so evident that the relation is easily apparent to every one. The only time when commerce and trade could get along even fairly well with relatively little aid from science was in the early days when the wild, uncultivated natural resources of the country were sufficiently abundant to support considerable traffic. But even in those days "when the world was so new and all," when the land was rich in wild fruits and game; when the streams and lakes and ocean banks literally swarmed with food-fishes of many kinds; when fur-bearing animals in marvelous abundance were found in the forests and along the streams; when the bays, sounds and oceans along our shores abounded not only in fishes of great commercial value, but also in fur seals, sea otters, whales and other important marine mammals that became the objects of great commercial fisheries, science had to be depended upon to navigate the ships and river boats, to direct the pack trains, to locate and capture the animals that were the objects of pursuit and properly to care for the animals and other products when secured.

And commerce has developed and grown and been able to maintain itself only as science has been able to lend a helping hand. Science points the way which industry must travel in order that commerce may live.

In the early days of civilized man's relations to the Pacific coast of America, trade was based quite entirely upon the wild, uncultivated natural resources of the country and of the adjacent sea. In the last decades of the eighteenth century the Russians came to Alaska and down the coast as far as San Francisco. They established permanent trading stations at Unalaska, Kodiak, Sitka and Ross near San Francisco Bay, and a temporary one on the Farallons, in order that they might hunt the fur seals and sea otters which then abounded in the waters of those regions. Only a

[1] Address delivered before the Commercial Conference held at Honolulu, October 26 to November 8, 1922, under the auspices of the Pan-Pacific Union.

little later, in the early years of the nineteenth century, adventurous spirits came from Boston, New York and New Bedford around the Horn to fish and hunt and trap; they came for the salmon of our rivers, the fur seals and sea otters of our coastal waters and the whales that then could be found in abundance from the Arctic Sea to Magdalena Bay. For more than half a century practically the only commerce on the California coast had to do with fur-bearing animals, fish, elephant seal, sea lions, whales and other products of the sea. It was the same on the coast of Lower California. On the coasts of British Columbia and Alaska fur-bearing animals and fish were almost the only objects of trade for more than a hundred years.

Alaska Fur Seal

When the Pribilof Islands in Bering Sea were discovered in 1786 by Gehrman Pribilof, they were the breeding grounds of vast numbers of the Alaska fur seal. The number that then frequented those islands has been variously estimated at from two to three millions. At first the Russians killed them, males and females alike, without any discrimination and without any thought of the future. But they finally began to realize that the herd was decreasing in numbers year by year, and more or less helpful regulations were established which afforded some protection. When the United States purchased Alaska in 1867 the herd was somewhat depleted, but still very large. During the period of transfer of jurisdiction and adjustment great slaughter occurred, but this was soon stopped and the government leased the islands for a period of 20 years (1870-1890) to the Alaska Commercial Company, under terms and restrictions which were fairly effective in conserving the herd. Only males were allowed to be killed; all the females were saved for breeding purposes, and, as the fur seal is a polygamous animal, and as the sexes are born in about equal numbers, the company was able to kill about 100,000 surplus young males every year without diminishing the herd in the least. A similar lease was given in 1890 for another period of 20 years.

So long as killing was confined to young males, the herd could not only be maintained, but there would be a substantial increase every year. In the early 80's, however, certain people at Victoria, San Francisco and elsewhere discovered that, by going out to sea in boats and falling in with the fur-seal herd on its return migration in the spring to the breeding grounds on the Pribilof Islands, they could kill enough to make the business very profitable. This was called "pelagic sealing," and the number engaged in the business increased rapidly and greatly.

When killing seals in the water females as well as males are killed; no selection can be made, as the sexes can not be distinguished in the water. On land the sexes can be distinguished and, under the government regulations, only young males were taken. As killing females destroys the breeding stock, the result was that the herd decreased rapidly until, in 1911, there were only about 127,000 left, as against more than 2,000,000 in 1873. Fortunately, the United States in 1911 was able to negotiate a treaty with Great Britain, Russia and Japan, prohibiting the killing of seals in the sea. This treaty was the result of scientific investigations which showed conclusively that the sole cause of the alarming decrease in the herd was pelagic sealing. All naturalists who had visited the seal islands and made any study of the question were unanimous in this opinion, and the Commissioners at the Fur Seal conference which met in Washington in the summer of 1911 were convinced that the scientific men were right.

Unfortunately, the law of August 24, 1912, giving effect to the fur-seal treaty, contained a clause prohibiting any killing on the land for a period of five years. This was a very stupid thing to do, for a certain number of surplus young males can and should be killed every year, not only without any injury to the herd but to the herd's advantage. As the sexes are born in equal numbers, and as one male to every 35 to 50 females is about the proper ratio of the sexes for breeding purposes, it is necessary to save for breeding purposes only a small percentage of the males. But the Congress refused to take the advice of those who knew most about the question and stopped all land killing for five years; and the then Secretary of Commerce, in his stupidity or stubbornness or worse, pronounced the law "very wise and sound legislation for the protection of our seal herds." So the five-year closed period ran its disastrous course. Thousands of male seals, no more needed for breeding purposes than are all the roosters hatched on a chicken ranch, instead of being killed when their skins were most valuable, grew up into old bulls whose skins are relatively of little value, thus causing a loss, directly chargeable to the man who happened to be secretary of commerce at that time, of between three and four million dollars and an injury to the seal herd that will require many years to correct. This is one illustration of the losses that are sure to follow when those directing industries refuse to listen to the voice of experts.

Guadalupe Fur Seal

It appears not to be generally known that fur seals were once very abundant on certain islands off the coast of California and

Lower California. I have recently looked up some of the old records and I was surprised to find that several of these islands were once the breeding grounds of large herds of fur seals. For example, more than 200,000 fur seals were killed on the Farallons, only a few miles from San Francisco and the Golden Gate, between 1806 and 1913. Many thousands were killed about the same time on or about San Miguel, Santa Cruz, Anacapa, Santa Catalina, Santa Barbara, San Clemente and San Nicolas islands off the California coast, and still other thousands at the Coronados, Guadalupe, the Benitos, Cedros and Natividad off the coast of Lower California.

The total number killed between 1806 and 1820 must have exceeded 400,000. At current prices of fur-seal skins these would be worth more than $20,000,000. The killing was done in the most reckless manner possible, without any regard whatever to the preservation of the species, with the result that the rookery on the Farallons was entirely wiped out by 1834. Not a single fur seal has been seen on those islands since that year, although it is not impossible that a few may be left on one of the uninhabited islands of that group.

It is known that fur seals continued to be killed about certain of the Channel Islands for many years after they were exterminated at the Farallons and at certain islands off Lower California as late as 1892. There is good reason to believe a few still persist about some of the isolated, unfrequented islands whose rocky shores contain caves which the fur seals frequent and in which they may escape observation.

The fur seal which occurred on Guadalupe Island, and, presumably, on the other islands off the coast of Lower California was the Guadalupe fur seal (*Arctocephalus townsendi*), a species distinct from the Alaska fur seal (*Callorhinus alascanus*) and, of course, distinct from the Russian and Japanese species (*Callorhinus ursinus* and *Callorhinus curilensis*). What the species was that frequented the Farallons and the other California islands is not certainly known, as there is no specimen in any museum. In all probability it was the same species as that found on the Lower California coast—the Guadalupe fur seal.

Southern Sea Otter

Another fur-bearing animal that was once very abundant on the coast of California and Lower California was the southern sea otter (*Latax lutris nereis*), a subspecies of the northern sea otter (*Latax lutris*), which is found in Alaskan waters and westward through the Aleutian and Commander islands to the Asiatic coast.

The pelt of the sea otter is the most valuable of that of any fur-bearing animal in the world, the skins often bringing as much as $2,000 to $3,000 each.

The early history of California makes frequent reference to sea otters and sea-otter hunting. Indeed, for many years sea-otter and fur-seal hunting constituted almost the only industry of that coast. Sea-otter hunting began there at least as early as 1786, and the industry developed rapidly. Sea otters were found all along the coast from Trinidad Bay southward. They were particularly abundant about the Farallons, among the Channel Islands and even in San Francisco Bay. They were abundant southward at least as far as the islands of Cedros and Natividad. One early manuscript (that of Vallejo) says "they were so abundant in 1812 that they were killed by boatmen with their oars in passing through the kelp."

In 1812 the Russians began to explore the coast, islands and arms of San Francisco Bay. The records show that they gathered great numbers of sea-otter skins. It is said that in some weeks they killed in San Francisco Bay alone as many as 700 to 800 sea otters a week. In a period of five years they took 50,000, and thereafter they took 5,000 a year down to 1831. One writer says that by 1817 the otter was exterminated from Trinidad Bay down to San Antonio Cove near San Francisco, but that hunting continued more or less actively at various places along the coast further south for many years. Some of the hunters hired Aleuts and bidarkas from the Russians and Indians from Mission San Jose, and did quite a good business for some time.

Particular places where sea otters were taken in large numbers as mentioned in the old records were the Farallons, San Francisco Bay, Purisima, Monterey Bay, San Luis Obispo, Santa Barbara, San Buenaventura, San Diego, Todos Santos and San Quintin; also San Miguel, Santa Barbara, Santa Cruz, Santa Catalina, San Clemente, San Nicolas, Coronados, San Benito and Cedros islands. Even as late as 1914 otters were occasionally killed about these islands, and it is known that a few still persist in certain favored localities.

While some of the early accounts are somewhat lacking in definiteness, and while there are many discrepancies, it is nevertheless clear that both the fur seal and the sea ottter were exceedingly abundant on the coasts of the Californias one hundred years ago. The total number of otters killed between 1786 and 1868 must have exceeded 200,000. At current prices these would be worth at least $200,000,000—a very neat little sum.

For a third of a century the hunting of these two valuable

animals constituted the only really important industry on the California coast. In those years scarcely a vessel came to that coast except for the purpose of trading in furs, and nearly every vessel that sailed away was heavily laden with these valuable natural products of the sea that washes the California shores.

It is equally clear that the sea otter, as well as the fur seal, was hunted in the most ruthless manner for immediate gain. That the killing might be done in a manner that would preserve the species in commercial abundance for all time as natural resources of enormous value seems never to have occurred to those engaged in the slaughter.

Elephant Seal

The elephant seal (*Macrorhinus angustirostris*) is another very wonderful animal that was once abundant on some of the islands of the California coast and southward. It, too, was destroyed in the same stupid way that the fur seals and sea ottters were commercially exterminated on our coast.

Until recently it, too, was believed to be extinct, but an expedition sent out from San Diego last July by the Mexican government and the Committee on Conservation of Marine Life of the Pacific,[2] with the cooperation of the California Academy of Sciences, the San Diego Society of Natural History, the Scripps Institution for Biological Research, the National Research Council and the National Geographic Society, found a very considerable herd on one of the southern islands. It will, therefore, be easy to reestablish this remarkable species as one of our important natural resources of great commercial importance. All that is necessary is an international treaty, rigidly enforced, for its protection.

Whales

The *whale fishery* has ever since its inception more than a century ago constituted one of the greatest and most romantic industries of the world. There has always been a strong and impelling fascination about whaling, and vessels have gone into the remotest seas in quest of these largest and strangest animals in the world. So persistently have they been hunted, and for so many years, that it is scarcely less than marvelous that there should be left to-day a single whale of any species anywhere in any ocean.

But we are now beginning to see the end of the 25 or 30 species of whales and other cetaceans known from the North Pacific;

[2] This is a committee of the Pacific Division of the American Association for the Advancement of Science, functioning under authority of the Committee on Pacific Investigations of the Division of Foreign Relations of the National Research Council.

several species that were once very abundant are now commercially extinct. The California gray is one of the six or seven species of whales that still occur on the California coast. In Scammon's time, 50 to 70 years ago, this whale was found on the coast of California in great abundance; in 1853 he estimated that fully 30,000 whales of this species visited California waters every year. The California Sea Products Company has been operating a whaling station at Moss Landing near Santa Cruz since 1918, and another at Trinidad since 1920, and they have taken only five California gray whales in all these years. The California gray is commercially extinct on the California coast. In the same period they secured 1 bottlenose, 1 sei, 4 sperm, 5 sulphurbottom, 19 finbacks and nearly a thousand humpbacks. It is, therefore, evident that the humpback is the only species of whale that is not already commercially extinct on the coast of California; that it, too, will soon be commercially extinct is equally evident.

SALMON

The salmon of the American and Asiatic coasts of the North Pacific are another of our great but vanishing natural resources. There are five species of Pacific salmon, some more valuable than others, but all very important. In habits they are all much alike. They are all anadromous; that is, they live most of their life in the sea and enter fresh water only to deposit their eggs. After having spawned once they all die, males and females alike; none lives to return to salt water. The eggs are deposited in the gravel or on other suitable bottom, usually in the fall of the year, and usually well toward the headwaters of freshwater streams. They hatch in the late winter or following spring, but not until some time after the fish that produced them have died. There is a period of several weeks each year during which each particular salmon family is represented only by a number of eggs. Both parents are dead and none of the children has yet been born; there are only a few eggs to tide the family over. It is, therefore, evident that *no Pacific salmon ever saw either of its parents or any of its children!*

There never was a greater natural resource in any country than the Pacific salmon, and none was ever more recklessly exploited and destroyed. That the industry has not long since been totally destroyed is no fault of those engaged in the business; only the vast abundance of the several species and their unusual and remarkable habits have saved them from complete extinction. Students of the habits of the salmon many years ago began to sound the warning and to tell the fishermen that their methods

meant eventual and inevitable ruin to the industry unless they changed their methods and curtailed their greed.

But they gave little heed to the warning of the naturalists who had made scientific study of the salmon. When the supply of Alaska red or sockeye began to fail, they turned to the less desirable species, the supply of which they believed inexhaustible; but even these are now decreasing rapidly. The sockeye situation everywhere is very serious; in the Puget Sound-Fraser River region it is most alarming.

Nothing short of an absolutely closed period of several years can restore the marvelous run of sockeyes that once entered those waters. There is no excuse whatever for the present deplorable condition. If the common and uniform regulations proposed by the International Fisheries Commission of 1908-1909 had been put into effect by the United States Congress, as Canada was ready to put them into effect, there is scarcely a particle of doubt but that the sockeye fishery of the Fraser River-Puget Sound region would to-day be equal to that of its palmiest days. But a few salmon fishermen (with votes) from Washington State were opposed to Federal control of the fisheries. So they went down to Washington, D. C., where they were joined by certain herring fishermen, also with votes, from Saginaw Bay. And being voters in this democratic government of ours, they had no difficulty in convincing our Senate Committee that the regulations which the International Fisheries Commissioners had proposed were all wrong, although said Commissioners with expert assistants had spent two years in field investigation and study of the problem.

For illustration, the Saginaw Bay fishermen claimed that the mesh of net proposed by the Commissioners for use in the herring fishery of Saginaw Bay was so large that it would not catch the Saginaw Bay herring. To prove their contention, they brought down to Washington a piece of gillnet of the sized mesh the Commissioners had proposed, and a bucket of Saginaw Bay herring. Two of the protesting fishermen held up the section of the gillnet, while a third fisherman picked up the herring by the tail and dropped them through the net. None of them caught in the net; they all passed through readily. And this was conclusive proof to the Senators that the Commissioners had proposed a net with mesh so large that it would prove utterly useless in catching Saginaw Bay herring. It apparently never occurred to any of the distinguished Senators that a Saginaw Bay fisherman who would have been so stupid as to carry down to Washington all the way from Saginaw Bay any herring that would *not* go through the net would be a very stupid Saginaw Bay fisherman indeed! So these

Photo by L. S. Slevin

A six-inch female embryo of a Humpback Whale fifty-one feet long and weighing forty-six tons taken in Monterey Bay, California, May 22, 1922, by the California Sea Products Company.

fishermen from Saginaw Bay and Bellingham with their convincing (!) arguments killed the treaty and, in killing it, they killed the Puget Sound-Fraser River salmon fisheries and the herring fishery of Saginaw Bay.

What I have said about the salmon fisheries of the Puget Sound-Fraser River region applies in almost equal degree to all salmon fisheries in the Pacific—the Sacramento, the Columbia and Alaska. Artificial propagation of salmon has probably done some good in some places; whether it has done any good whatever in Alaska may well be questioned. One outstanding fact, however, is evident, and that is that the methods, regulations and ideals employed in those fisheries must be radically changed if those fisheries are to be restored to, and maintained at, their former productiveness.

Halibut, Herring, Etc.

The halibut, herring and other fisheries of Alaska and elsewhere in the North Pacific are also passing and must receive the serious attention of the various governments concerned if they are to survive.

The Pacific Rich in Natural Resources

The natural resources of the Pacific are the richest and most varied of any ocean in the world. Of marine mammals, I do not know just how many species there are. Recently I was able to compile a list of at least 44 species that occur in the North Pacific: 9 baleen whales, 5 sperm whales, 12 porpoises, killer and dolphins,

From Scammon

Right Whale, the great northern baleen whale of the north Pacific. It attains a length of sixty to seventy feet. It would produce about one hundred and thirty barrels of oil and one thousand to fifteen hundred pounds of baleen. Formerly abundant, especially from Oregon northward, now rare.

a total of 26 cetaceans; and 1 bear, 2 sea otters, 4 fur seals, 10 sea lions, elephant seals and harbor seals, and 1 walrus, a total of 18 carnivores, or 44 in all. There are probably more; I do not know.

And this very richness of natural resources has made Americans the most shortsighted, the most extravagant, the most wasteful people in all the world. There is not one of these resources which, in the beginning, was not handled in very wasteful ways; in numerous instances so wasteful and so destructive that the resource has been commercially destroyed.

Most fishermen, *not all*, are short-sighted; they lack vision; they conduct their business as if only for the present; they keep the goose laying while the laying is good. But observation points out the inescapable fact that the laying capacity of any goose is limited, and that when that limit is reached there must be another goose ready and able to "carry on," else the golden-egg industry "croaks." Too many business men are ready to milk the cow to the very strippings and then "bump off" the cow.

The paths of industry are paved with the empty shells of natural resources, that, instead of being conserved and made the bases of going concerns, were eviscerated in their infancy.

Productiveness of the Sea Easily Maintained

The natural resources of the sea are very different from those of the land in that they can be renewed from year to year, and, with proper management, kept reproducing themselves indefinitely. Not so with most of the resources on the land. Every ton of coal mined and consumed decreases by just that amount the supply

From Scammon

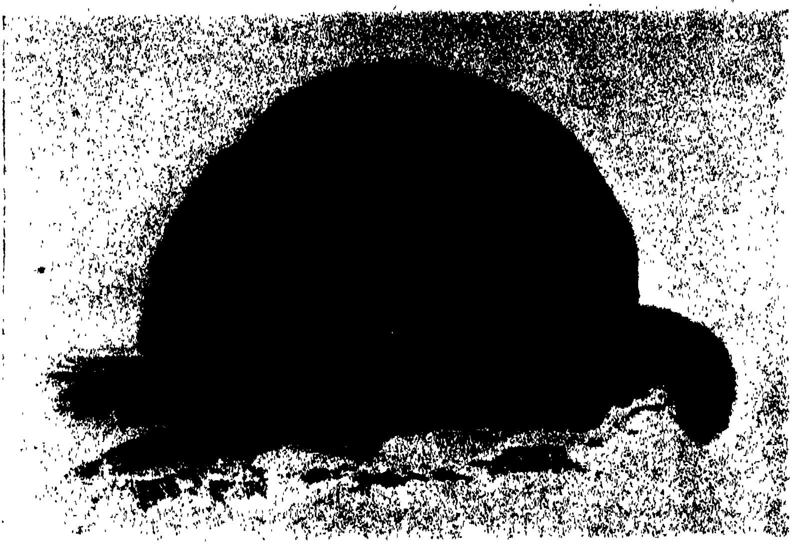
BANDED SEAL

This beautifully marked seal, of which very little is known, is said to occur on the coast of Alaska and Asia. In April, 1852, Scammon saw a herd of what he believed to be this species on the beach at Point Reyes, California.

of coal in the world, for we know of no way by which to make another ton to take its place. The same is true of gold and silver, copper, and lead and iron; oil, natural gas, and all the other minerals in the world. Synthetic chemistry with these things has not yet reached a commercial basis.

Many of the animal and plant resources of the land must inevitably disappear before the advance of civilization. The existence of great herds of buffalo, elk, antelope and other game animals is incompatible with the clearing up of the country and the cultivation of the soil. It seems impossible to preserve our rivers and smaller streams as fit environment for the food-fishes which once abounded in them. What with pollution of various kinds and other changes in the character of the streams caused by cutting off the forests, draining the swamps and cultivating the soil, it is only a question of time, and not very long at that, when clear, pure streams teeming with delicious food fishes will cease to be.

Nearly everywhere the natural richness of the soil has already become so exhausted that fertilizers must be used to insure any crop at all. Soil experts warn us that, in many regions where irrigation has been carried on for a long time, the soil is becoming poisoned by mineral salts left behind by evaporation and inadequate run-off. The supply of fertilizer in the world, or that can be manufactured, is limited and may be exhausted all too soon, except perchance that which can be made from the animal and plant resources of the sea. As time goes on, the soil will become more exhausted and, consequently, less and less productive, and the



From Scammon

SEA OTTER

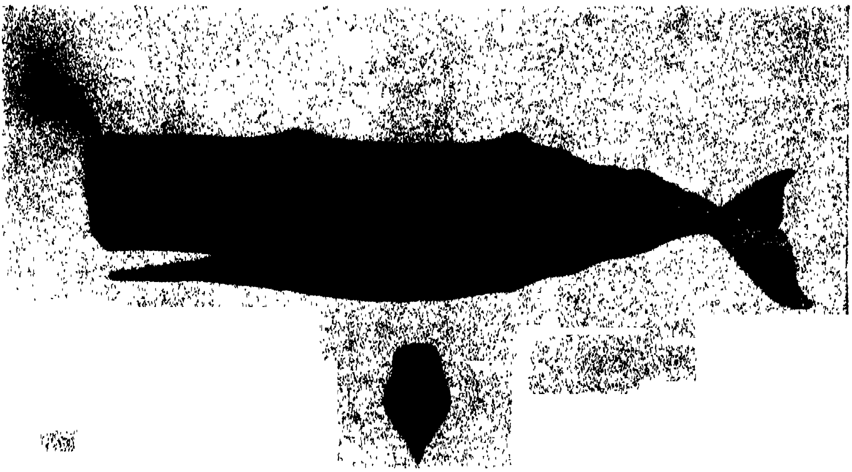
The fur of the Sea Otter is the most valuable of that of any fur-bearing animal in the world; the skins often sell for $1,000 to $3,000 each. About one hundred years ago this animal was very abundant on the coast of America from Bering Sea to Lower California; more than fifty thousand were killed on the coast of California alone, many of them in San Francisco Bay. Those pelts would now be worth more than $50,000,000.

world will have to depend more and more on the products of the sea for its food supply.

So I repeat, when natural resources are considered, the sea is quite different from the land. Man's activities must necessarily gradually and forever reduce and finally exhaust all mineral resources, and permanently and in ever-increasing degree decrease the natural animal and plant resources of the land, and even the fertility of the land itself even to complete exhaustion.

Man can and doubtless will in time so modify or change the land environment that it will no longer be possible for our natural animal and plant resources on the land or the fishes in the streams to maintain themselves in commercial quantities, but he can not greatly change the character of the sea. Old ocean remains unchanged in any vital way, and will, so far as we can tell, always so remain. It is true there is some contamination of the sea by oil from tankers and motor boats, which destroy certain water birds and may do considerable harm to the surface-swimming young as well as the food of some fishes, but this can easily be avoided.

The ocean environment to-day is just as good for fur seals, sea otters, elephant seals, sea lions, walruses, whales, salmon,



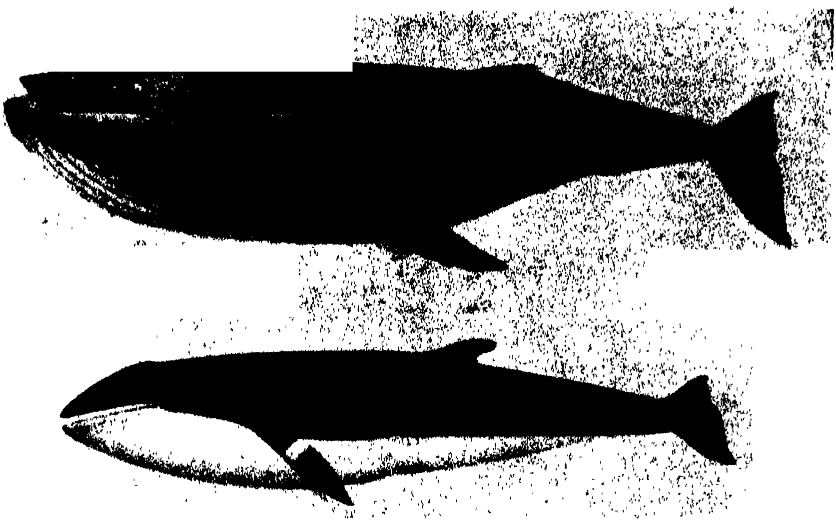
From Scammon

Sperm whales are gregarious, and, before they became so nearly exterminated, were often seen in schools numbering fifteen to twenty, and sometimes as many as one hundred. It attains a length of eighty feet or more.

The species is now very rare on the coast of California, only five having been taken in those waters in four years.

sharks and sardines as it ever was. We do not have to add expensive fertilizer to the ocean to make it produce. The ocean is self-fertilizing; it is kept fertile automatically. Professor Baird and Professor Brooks used to say that an acre of water has a greater productive capacity than an acre of land. I believe the statement to be true. The animal and plant resources, unlike coal and copper, iron and oil, are self-renewing. As I have already said, when a ton of coal is taken out of the mine and consumed, the world's supply of coal is permanently decreased by just one ton; so far as we know there will never again be as much coal in the world as there was before that ton of coal was consumed. Not so with seals, salmon or sardines. Kill a hundred thousand this year and next year there will be just as many as before. Such resources as these are self-renewing.

All that is necessary to maintain the various natural animal resources of the Pacific in a condition that will make each of them the basis of industries of enormous commercial importance is to afford them that protection which will insure a normal annual increase at least equal to the annual kill. Do just that and let nature take its course; that is all that is necessary. But how can that be done? How can we protect the fur seals and the other marine mammals and the fishes so that the species may be restored to, and maintained at, their former abundance, and at the same time permit large commercial catches each year?



From Scammon

HUMPBACK WHALE (*MEGAPTERA VERSABILIS*)
SHARP-HEADED FINNER (*BALÆNOPTERA DAVIDSONI*)

Of the six or seven species of whales that were at one time more or less abundant on the California coast all are now commercially extinct except the Humpback, of which about one thousand have been taken in the last five years. It, too, is nearing commercial extinction.

The Sharp-headed Finner is one of the smallest and rarest of whales. It rarely exceeds twenty-seven feet in length. It occurs from Mexico to Bering Sea.

All of these animals spend more or less of their lives on the high seas beyond the three-mile limit. Most of the killing of many of them, such as the sea otters, fur seals and the whales, is carried on beyond the three-mile zone. On the high seas all countries have equal rights. In the absence of international treaties, anybody of any country has a perfectly legal right to kill fur seals, sea otters, whales or any other animal, and to fish anywhere outside the three-mile limit.

The fur-seal treaty of 1911 entered into by the United States, Great Britain, Russia and Japan protects, so far as those four countries are concerned, the three species of northern fur seals and the northern sea otter north of the 30th parallel, but it does not protect them south of that parallel; nor does it protect them against the nationals of countries not parties to the treaty. There are small fur-seal herds still left on certain islands off the coasts of Mexico, Ecuador, Peru, Chile, Uruguay, Argentina, Australia and New Zealand, and on various islands down toward the Antarctic (South Georgia, Kurgelens, South Shetland Islands, Sandwich Land and others). It would be perfectly legal for a vessel

After Scammon

HUMPBACK WHALES LOBTAILING, BOLTING, BREACHING AND FINNING

The Humpback is the only whale now found on the California coast in commercial abundance. The usual length is thirty-five to fifty-five feet and the weight thirty to fifty tons. During the past five years it constituted more than ninety per cent. of the catch on the coast of California.

flying the flag of any country in the world, except that of the United States, Russia, Great Britain or Japan, to hunt and kill fur seals and sea otters anywhere in any ocean in the world; and it is perfectly legal for a vessel flying the United States flag, or that of Russia, Great Britain or Japan to go south of the 30th parallel of north latitude and kill fur seals and sea otters on the coast of Mexico, Ecuador, Peru, Chile, Uruguay, Australia, New Zealand or anywhere they can find fur seals or sea otters, provided the killing is done outside the three-mile limit. And that this may be done some time is not at all improbable. The only thing that will prevent it is an international treaty for that specific purpose.

I have no doubt but that fur-seal rookeries can be re-established on the Farallons, the Channel Islands, the Coronados, Guadalupe and the Benitos. Such rookeries would in time yield to the United States and to Mexico an annual income of more than five million dollars in revenue. It will be equally easy to re-establish the southern sea otter in California and Mexican waters and that would mean two or three million dollars income to the two countries. The annual catch of fur seals and sea otters in these waters would easily be worth ten million dollars. And the value of the annual product in oil, fertilizer, chicken feed and leather of the whale, elephant seal, sea lion and porpoise fisheries when they shall have been re-established, as I am confident they can, would add several millions more. Then there are the fisheries proper—the salmon, halibut, herring, cod, tuna, sardine and many other species that frequent the high seas and which can be developed to, and main-

An old picture from Scammon illustrating the former abundance of the California Gray Whale. Fifty years ago many thousands visited the California coast every winter. Only five have been taken in the past five years.

tained at, that standard of productivity of which they are easily capable; these would add enormously to the wealth of all the countries concerned.

Mention must be made also of the sea turtles formerly very abundant on the coast of Lower California and on many other shores of the Pacific. Nor should I fail to call attention, if even but briefly, to one other natural resource of the Pacific which has not usually been regarded as of any importance and that is the sea birds. Their value as producers of guano is well known, but the possibility of their ever becoming valued for their feathers and eggs, and as food, has not received much attention. That they will in time be sought for these purposes is certain, and they should be protected for this reason as well as for reasons esthetic and zoological.

The remarkable rapidity with which the Alaska fur-seal herd increased during the last 10 years under the protection of the fur-seal treaty of 1911, an increase from 127,000 in 1911 to more than 600,000 in 1921, which permitted a kill in 1922 of 30,000 seals valued at \$1,500,000, demonstrates what a depleted natural resource of this kind will do when given proper protection through international cooperation. The world needs a similar but more comprehensive treaty covering not only the other fur seals of the at present unprotected areas, but the sea otters, elephant seals, whales, walruses, fishes and other natural resources of the sea.

Such a treaty by the various countries of the Pan-Pacific Union and other countries interested would, in a few decades, result in rehabilitating these depleted resources to an extent that would permit for all time an annual product of at least five hundred million dollars.

If these various aquatic natural resources are to be saved, it is important that cooperative action be taken soon by the various countries concerned. An international convention should be called at the earliest date possible to which all maritime countries should be invited to send commissioners to consider the fisheries of the Pacific, or even of the world, in their international aspects. This convention could, with data already available and that can be readily assembled, negotiate a treaty for the protection, rehabilitation, conservation and proper utilization of all the fur-seal herds of the world not already covered by the treaty of 1911. This treaty should be modeled after that of 1911.

This convention could also provide restrictions or closed periods of adequate duration for whales, sea otters and other vanishing species concerning which present knowledge is inadequate for definite and final action as to the conduct of commercial fishing when the species have been restored in commercial abundance.

There are many scientific problems pertaining to the oceanography, meteorology and biology of the North Pacific that must be more fully understood before we can be in a position to say just what regulations will best protect certain of the natural resources of the North Pacific. For example, we do not know (a) just what relation the whales bear to the other fisheries, (b) the best way of protecting the whales and at the same time permitting the whaling industry to continue, (c) the relation of the Orca or killer whale to the fur-seal herd, (d) the relations of the various species of sea lions to the salmon and other fisheries, and (e) the factors that determine the abundance and distribution of marine species, their breeding seasons and places, their migration routes, their food and natural enemies. There are many other problems needing scientific study. An international commission similar to that for the exploration of the North Sea, which has done so much for the commercial fisheries of the North Atlantic, is what I have in mind. A commission like this is needed to secure the facts and figures and other data which will be necessary for full understanding and scientific development and regulation of the fisheries.

What a splendid thing it would be if fur-seal rookeries could be re-established on the Farallons and on the numerous other islands on the coasts of California and Mexico, and on the scores of

islands in the South Pacific and in other southern waters which they once frequented in such marvelous abundance; if we could bring back the sea otter in the various waters in which it has been commercially exterminated; bring back the wonderful elephant seal, the walrus, the whales, other marine mammals and the salmon; learn to utilize rationally the many other natural resources of the sea, and bring about conditions which will enable the industries based on those resources to be maintained as going concerns for all time!

These things can be done. All that is necessary is prompt and intelligent cooperation among the countries represented in the Pan-Pacific Union. I can conceive of no more important movement for the gentlemen of this commercial conference to approve and get behind and urge upon their respective governments.

OBSERVATIONS OF BIOLOGICAL SCIENCE IN RUSSIA

By Professor H. J. MULLER
UNIVERSITY OF TEXAS

IN thinking of his Russian colleague the American scientific worker usually pictures to himself a starving creature in rags, hiding in some attic, where perhaps he may be clinging despairingly to his microscope and to some few remaining books. I found the reality different. The Russian scientist I saw was busily engaged in his laboratory, actively interested in his scientific work and getting results, and desirous above all of getting into touch with the work that the west is producing. At present that is a most difficult undertaking for him, since he can not buy our publications and travel either to or from his country is beset with numberless complications.

These complications affected my visit also, but through the initiative of Dr. Borodin, who is in New York collecting reprints on plant breeding and related topics for the Russian Bureau of Applied Botany, and of Dr. Ivanov, whom I met in England, where he was arranging to obtain material for animal breeding in Russia, I was eventually enabled to obtain the necessary visés to enter the country, and letters of introduction to scientists. Once the lengthy preliminary arrangements had been made, there was no time to be lost, and the journey from Germany by monoplane direct to Moscow was made in about nine hours. To the scientist there any foreign visitor, bearing the longed-for news of the discoveries made in America, is a "windfall," and so I found a most hospitable reception awaiting me from the Russian biologists and was most kindly conducted by them to all the people and through all the institutions that, in my three weeks' stay, I had the time to see.

I found many of the biologists gathered together into a series of large state "institutes," which have developed since the revolution. In Moscow eight of these institutes, including some more strictly medical in nature, are grouped together under the Ministry of Public Health. (See the table listing these and other institutes, in *Science*, April 20, 1923.)

The Institute of Experimental Biology, under the leadership of Professor Koltzof, a man of extremely broad interests, carries on work in various fields—genetics, experimental morphology, ani-

mal behavior, ecology and general physiology. The genetics, under the immediate charge of Professor Lebedof, is carried out at the station of Anikovo, thirty miles out in the country, and near by this is another branch of the institute, the hydrobiological station under Skadovsky. The two together number about forty or fifty scientific workers. At the genetics station some hundred different genes are being studied in chicken crosses. The inheritance of the three sex-linked genes for barring, silvery and short tail is being studied simultaneously here by Serebrovsky, and he has observed crossing-over between them independently of the work of Goodale and of Haldane upon two of these factors, reported in *Science* within recent years. Guinea pig and rabbit crosses are also being made. The latter work, too, is running parallel to what has been found in this country as, for instance, in the case of the finding of a pink-eye-producing, coat-diluting factor like that discovered by Castle a few years ago in guinea pigs from Peru. In the absence of means of communication such duplication is inevitable, and much effort of the highest type must be wasted, to the disadvantage of science in all countries. All the work is not being paralleled here, however. For example, the inheritance of the amounts of enzymes in the blood is also being worked out, the enzymes being measured quantitatively by methods of Professor Bach of the Biochemical Institute. I have not time to describe the various other interesting activities of this station, such as, for example, the biometrical work of Romashof, or the work of Kogan on transplantation of gonads, with rejuvenescence, in fowl, finches and rodents. At this station T. H. Morgan is regarded as the great leader of

FIGURE 1. GROUP OF WORKERS AT THE GENETICS STATION AT ANIKOVO. The men from left to right are: Romashof, Serebrovsky, Lebedof, Kogan (sitting) and Shivago.

modern biology, and "The Physical Basis of Heredity" has already been translated into Russian by Lebedof.

The history of the genetics station typifies the terrible struggle against hard economic conditions, rewarded with ever-increasing measure of victory, which many of the scientists have been waging for nearly six years. The land and some buildings were allotted to it in 1919, but practically all the installations, the bringing in of material and the other actual physical construction work had to be carried on by the scientists themselves amidst almost inconceivable difficulties at every smallest step; not least among these was the desperate food shortage, and the construction work accordingly included the setting up of a farm to raise many of their own supplies. They stuck it out, however, and to-day they have not only a fairly reliable food supply, but also serviceable laboratories and breeding houses, with the necessary apparatus, telephone, running water, etc. Whereas in the earlier period they could do little with the animals but to keep the stocks going, they are now finding themselves in a position to do more and more actual experimentation.

It is interesting to observe how the station and its workers derive their support. This comes from a combination of sources, each branch of the government that is interested in the work contributing something, though there is not nearly enough from any one source to run the station. Thus, the Ministry of Public Health, regarding biology as fundamental to it, makes important contributions. The Ministry of Agriculture does similarly. In addition, those members of the station who are at the same time connected with the university receive salaries from there. Quite apart from these sources of support, each scientist draws from the state a certain wage just for being a scientist—which, however, in the case of scientists of the first of the five degrees of eminence into which they are divided amounts to only about $15.00 a month (about half the total salary of many German scientists, but money can buy much more in Germany). And besides this wage in money the scientist draws his monthly *payok*, or food ration. Putting together these various individually very insufficient items of income, the workers at this station seem to obtain enough to cover their most essential needs—of course, not in the style in which these would be taken care of in the still comparatively wealthy countries west of the Rhine, but at any rate sufficiently to enable them to do effective work.

The situation was entirely different from this three years ago. Then, in spite of the attempt at universal *payoks*, the entire city population was slowly starving, and most of the scientific workers lost about 30 pounds in weight. But since that time, despite the still awful famine in the south, agricultural conditions in the

country as a whole are improving and trade is reviving; and this in turn is being reflected in an undeniable improvement in the physical condition, efficiency and hopefulness of the people in general, including many of the scientists.

Though it would be difficult to say just how far the economic condition of these Anikovo scientists whom I have taken as examples is typical of the condition of Russian scientists in general, I met many others living in the city who seemed to be in rather similar economic circumstances. This should not be interpreted as meaning that they were well provided for, according to our point of view, and any assistance which we might render by way of helping to improve their condition could scarcely be better placed, but we ought to realize in so doing that we are helping people who are also actively helping themselves and who are by no means scientifically bankrupt. They are doing work which is well worth while, but which might be still more so if we could lend a cooperative hand at certain crucial points.

It would seem, however, from the urgency of the appeal for aid to Russian scientists issued by Gorki last year that there must also have been other scientists who were in much more dire distress, and those would, of course, have been the very ones whom I would have been least likely to meet. Strange to say, I did not hear of any of these while I was in Russia, although the scientists with whom I spoke were by no means desirous of concealing disagreeable information. In order to get some sort of gauge of the losses that had been suffered by science, I asked the workers at Anikovo what proportion of all those who had been engaged in scientific pursuits in Russia before the war were estimated still to be in the country and at their work. The answer was "two thirds." Of the remaining third, caught in the wars, revolutions and famines, part had emigrated, part were dead and part had left their calling. The proportions of each of these were very uncertain. Naturally, those who had opposed the revolution on the whole fared worse than the others. It should be emphasized, however, that at the present time the political opinion of a Russian scientist is not a bar to his obtaining a position if he has not actively concerned himself with political matters. There seems to be a greater amount of political tolerance now than at any time since the revolution. Though most of the scientific workers have always been anti-communist, yet since the government is attempting to support science, they are becoming workers in state institutions. Thus, Professor Koltzof, although he was in jail for several months three years ago for political reasons and even for a time under death sentence, is to-day head of the Institute of Experimental Biology. Several of the Anikovo workers have a similar

history. When I last saw Professor Koltzof he and his family were living in a well-appointed apartment, with a servant, and he was about to leave for the Crimea on a long needed vacation.

Criticism of the government is very common among the so-called "intellectuals" and seems quite open, but it is not expected that there can be any new overturn. The revolution is universally regarded as an accomplished fact, unavoidably entailing both good and evil, and most of those of all shades of opinion who wish for a political change—whether to right or to left—believe that it can be effected gradually from within. On the whole, however, the scientists whom I met do not actively concern themselves with politics at all; they are too busy with science.

Returning from this digression to our review of the Institute of Experimental Biology, it may be recalled that near the Genetics Station at Anikovo there was the Hydrobiological Station under Skadovsky. This is conducting investigations on H-ion concentration, particularly with a view to its influence on the microorganisms in the water of peat bogs. The position which Morgan occupied at Anikovo is here taken by Loeb, and the two adjacent stations regard themselves as rivals—Morganites and Loebites, respectively.

Koltzof's experiments on animal behavior, urodele development, etc., are being carried on at the headquarters of the institute in Moscow. In the same building are also located the Institute of the Physiology of Nutrition, the Institute of Tuberculosis and that for the Control of Vaccines.

The Institute of Tropical Medicine, under the general direction of Martsinovsky, comprises a large staff and is exceedingly active. Many cultures of protozoan parasites—malaria, trypanosomes, etc., are being propagated and studied. The Leishmann-Donovan organisms, for example, are carried through their entire cycle—both flagellate and sporozoan stages—in vitro. The effects of quinine and various other chemicals upon such cultures is being studied intensively. Entomological and helminthological researches are also being conducted, as well as work of a more directly practical nature, aimed at the immediate control of the diseases. The latter is carried on not only in the laboratory but also by the aid of the attached clinic, through ecological studies in the field and expeditions to all parts of the country. Among the ecological results, for example, is the finding that malaria may be partly controlled by fostering the growth of the common water plant *Utricula*, which has been found to catch mosquito larvæ in large numbers. Finally, there is a department which aims to teach physicians and another to teach laymen through courses, demonstrations, museum exhibits

and literature the best measures of prevention and treatment as found in the theoretical departments.

Many readers will remember that there was an account in the papers last spring of the discovery of the typhus germ in Russia. The finding of this germ—which is now fairly definitely determined to be the cause of typhus—was really made several years ago by Barikin, head of the Institute of Microbiology; and at the same time Barikin found a way of keeping it in vitro for a short while. But last year, with the aid of Dr. (Miss) N. Kritch, he succeeded in getting a method of propagating it in vitro indefinitely. Besides typhus, cholera, plague and other pathogenic microorganisms are being studied by Barikin and his staff. They are doing extensive theoretical work on the effects of selection on their cultures and have succeeded, for example, in changing one "species" of Proteus into another and in altering the agglutinating capacity of cholera organisms. In their immunology department they are making various investigations into the nature of antigen-antibody reactions, the relation between amount and speed of action of antibodies, manner of summation of effects of different sera, etc. Here, too, there is a medical department attached.

The Biochemical Institute of Professor Bach is handsomely fitted up and also has many workers. It is here that the methods were developed for measuring quantitatively the amounts of various enzymes in a single drop of blood, which the genetics station workers are applying in their heredity studies. Professor Bach will also be the head of the large Chemical Institute, the building of which is being erected nearby. This will include about forty chemists and their assistants. The hard economic condition of Russia has prevented any building from being put up in Moscow for the last two years, despite the frightfully overcrowded condition of the city—with this one surprising exception, a building which is to be devoted mainly to the purposes of pure science!

All the institutions have not fared so well. For example, Professor Ivanov, the sperm specialist, who has developed the method of artificial insemination in domestic animals to the point where twenty-five times as many females can be successfully impregnated as through natural coitus, at the same time killing off the pathogenic micro-organisms which may be transmitted in the sperm and thus preventing the spread of venereal disease, says that he can not even get the simple apparatus—syringes, sponges, etc.—in sufficient quantities for distribution to the various animal breeding stations scattered over the country to enable them to reap the practical results from his methods. Things are in a state of flux, not yet sufficiently organized to give with equal justice everywhere.

Professor Lazaref, on the other hand, head of the Institute

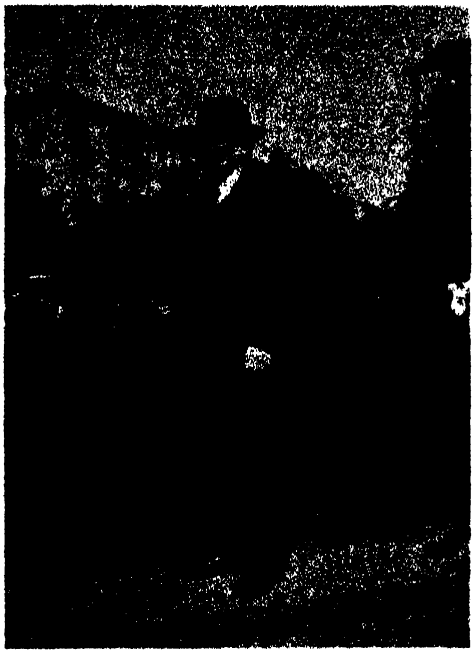


FIGURE II. PROFESSOR IVANOV (taken in Berlin, 1922).

of Biophysics and Physics, has been working undisturbed through war and revolution in his magnificent, well-equipped building, built in 1917, two months after the overthrow of the Czar. With his staff of forty skilled scientists and numerous laboratory helpers and assistants, he is directing a system of complicated and coordinated researches into the physico-chemical mechanism of excitation and conduction in protoplasm. Starting out with Loeb's quantitative law expressing the antagonistic action of mono- and bi-valent ions on proteins, he derives curves showing the amount of excitation at the cathode, due to the faster accumulation there of the monovalent faster moving K ions than of the heavier Ca and Mg ions. These and other theoretical curves, including curves of the energy relations involved, he tests out in precise physico-chemical experiments involving the senses of sight, hearing and taste. He finds his hypotheses substantiated and—as one outcome—in the case of all these senses he finds the actual energy involved in stimulation to be the same, as his theory required. He has carried his work further, to the mechanism of conduction of the excitation and beyond that to important theories and experiments on the happenings in the central nervous organs. In terms of the periodical electrotonus which results from the activity of such centers he can interpret various phenomena of reflexes and imitate them in arti-

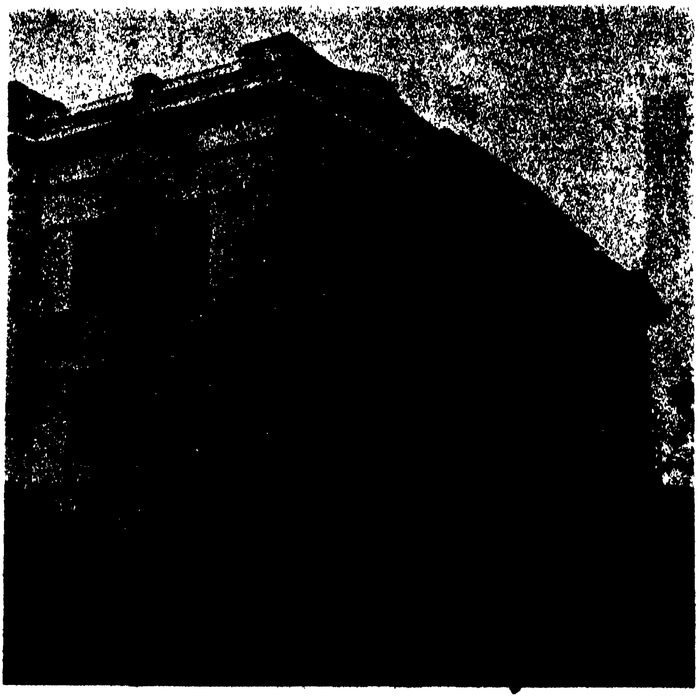


FIGURE III. A PORTION OF THE INSTITUTE OF PHYSICS AND BIOPHYSICS OF PROFESSOR LAZAREF (taken soon after its construction).

ficial models. The electromagnetic radiations caused by these processes he believes may also be important in causing one center to influence another.

Professor Lazaref was trained originally as a physicist. Only one half of his building is devoted to the biophysical researches; in the rest he directs a series of investigations in molecular physics and photochemistry. Thus he has a great advantage over most biologists when he treats the physical and mathematical problems of biology, and a study of his work should prove of value from the methodological standpoint by itself. Concerning the ultimate value of the results, it would be hazardous to predict precisely. It would be very remarkable indeed if Lazaref's whole elaborate system of theories of sensory and neuron action eventually proved correct in all details, but so much careful work, experimental as well as mathematical, has already been expended on it, that it is bound to contain very important contributions. As the absorbing account of this work was rapidly unfolded to me by Lazaref, the conviction was forcibly borne in upon me that other Americans, could they hear his expositions, would be similarly impressed, and that if Professor Lazaref were to visit this country and give us talks along these lines, our own biological science—or at least that

section of it which could appreciate his work—would be profoundly stirred. Not improbably the shock of contact with this foreign development would stimulate a whole new school of American researches.

There are various other institutes in Moscow in which work of some biological nature is in progress, but of these—the aims of which were often practical or semi-practical, such as agricultural or hygienic—I do not have time for details. Suffice it to mention in this connection only the excellently fitted out Institute of Work, under the physiologist Kekcheyef and the engineer Gastev, which, with a staff of about thirty scientists and seventy helpers, is trying to work out on a scientific basis various acts performed by laborers, to deduce from these analyses the methods of performing these acts that are most efficient from a mechanical, psychological and physiological standpoint, then to find the best ways of teaching the methods to workers, and finally to test them out in the attached factories. Mental testing for occupations and the organization of work is also being studied here. At present the course

FIGURE IV. PROFESSOR LAZAREF, HEAD OF THE INSTITUTE OF PHYSICS AND BIOPHYSICS.

of the hammer stroke is being examined most intensively, and a mathematical formula has been found for the energy changes in the stroke, which has been analyzed by cinematographic records, ergographs and various other means.

Many of the main scientific institutions that are not connected with universities center in Moscow, but considerable work is also being done elsewhere. Unfortunately there was not enough time left to me for Petrograd to enable me to see any institutes there except the Bureau of Applied Botany, under Professor Vavilov— who, as is generally known, visited America last year. Though the offices are in Petrograd, the main genetic work is done on the estates of the former nobility at Tsarskoye Selo, which was the home of the Czar and was the Versailles of Russia. The genetics station building shown in the picture was formerly the mansion of the Grand Duke Michael Nicholayevitch, and had been presented to him by Queen Victoria. The bizarre buildings of the monk Rasputin, given him by the Czar, are also being used, by another group, for scientific agricultural purposes. The genetics station is a center for plant breeding work all over Russia and has over a hundred plant breeders and helpers connected with it in various parts of the country. Vast collections of varieties of food plants— especially cereals—are being made and classified at the station, and they are tested out here on a great scale with a view both to the finding of the best varieties for practical uses and also to the discovery of theoretical principles of variation. Thus Vavilov has found his so-called "law of parallel variations" that the same series of variations occurs in all the species of a group, and after

FIGURE V. GROUP OF WORKERS AT GENETICS STATION OF THE INSTITUTE OF APPLIED BOTANY AT TSARSKOYE SELO. At the extreme left is the director, Professor Vavilov, and on his right, Professor Berg.

classifying the variations of, say, wheat, he can use exactly the same system to represent the variations of rye or barley. Study of the geographical distribution of the varieties throughout the huge extent of European and Asiatic Russia has also led to interesting results and in several cases made it possible to determine the point of origin of a cereal. Besides the more descriptive studies crosses are being worked out, the most important of which are probably those of wheat-rye hybrids.

Professor Berg, shown in the dark cloak in the picture, seeks support in this cereal work for certain rather unique theories of orthogenesis. Embryology, claims Berg, not only recapitulates the past, but to a certain extent predicts the future, which is predetermined within the germ plasm rather than decided by natural selection. It is a curious commentary upon the present situation in Russia that when I mentioned to him the fact that the legislatures of some of our states are seriously considering bills prohibiting the teaching of evolution he countered by declaring warmly that his book, explaining the above theory of predestination, was being held up by his government; publication was stopped and his manuscript being gone over by the authorities, who regarded it as a pernicious and subversive doctrine since it was opposed to Darwinism!

The large research institutes above described do not have a monopoly in research, but of that done by individual scientists in the universities I had less time to learn, except at second hand. There is, for example, in Petrograd University the animal geneticist Philiptchenko, known especially for his work on rabbits and on bison hybrids. Interesting transplantation experiments on hydra, involving grafts from one species to another, have recently been completed by Isayef, also in Petrograd University. The new book on sex and secondary sexual characters, by Savadovsky, of Moscow University, is already known in this country. Madame Nikolayeva, at the Agricultural College in Moscow, has some cytological work, reported to be very interesting, on chromosome aberrations in cereals, which unfortunately I had no time to see. Pavlov is at work in Petrograd, and is supplied with all facilities possible for his research, although I am told that the hard conditions of life of the people in general have affected his spirits, so that he has been unable to work with the enthusiasm of old. For most of the university workers, too, economic conditions are still very hard, as measured by our standards. They are slowly improving, however. So far as their university duties are concerned, there is plenty of time for research work, and this, in fact, is said to be expected of them. I was told by Madame Yakobléva, head of all the universities, that the professors ordinarily lecture between six

and ten hours a week and in laboratory subjects a few additional hours may be spent in the direction of the laboratory work. This compares well with the hours prevalent in America.

In connection with the teaching of biology in the universities, I was rather surprised to be told by one of the prominent younger investigators in a Moscow research institute that this work is still dominated by men of the older school in biology. In Russia, as in most other countries, the majority of the "old line" authorities have a semi-morphological manner of regarding living things. Thus, in spite of the far-reaching changes in educational procedure and in general point of view in Russia, there has, as yet, been no overturn in the manner of teaching biological science, such as is even now taking place in a few of our American colleges where men of the younger generation, with its predominantly physico-chemical viewpoint, have happened to gain the leadership.

It is said that new students are still being drawn into research work in Russia. Of course only a small proportion of those entering the universities ever go into pure science, but it is encouraging to find that more are receiving some sort of education than ever before. This is one of the undisputed benefits conferred by the revolution. It applies not only to the lower sphere of education, which, I was told by Vavilov, has spread so among the ignorant peasants, formerly so largely illiterate, that already the majority can read. According to Yakobleva, there are about 135,000 students in the colleges and universities. Those who wish to and can afford it may go by paying their way, but the majority are sent by various organizations of workers. Although a new movement was inaugurated with the revolution, attempting to make higher education more accessible to all by allowing workers and peasants to attend after passing a preparatory course of only three years, nevertheless four fifths of the students still enter after the regular preparation, as before. Tremendous difficulties are encountered in thus endeavoring to enlarge the educational system amidst the economic crisis and famine. Thus, a new university was started last year in the Crimea. The professors went there, but when they arrived there was no means of existence—no food at all—and professors and students dispersed. Again, last winter the *payoks* arrived late at the university in Moscow; this caused a strike of the professors, and the situation was remedied.

But the most engrossing concern of the Russian scientists whom I met at the present time is neither political nor economic—it is with their work. And the main difficulty of most of them in this now is their isolation: their inability to obtain knowledge of the progress being made in other countries and to exchange ideas with

the west. The geneticists at Anikovo had never heard of East and Jones's book on "Inbreeding and Outbreeding," of Babcock and Claussen's "Genetics," of Lillie's "Problems of Fertilization," of Holmes's "The Trend of the Race." They did not know of any of the American work which partly paralleled their own. They have never seen *Genetics*, and have not seen *The American Naturalist*, *Journal of Experimental Zoology*, *Proceedings of the National Academy of Sciences*, *Science* or *Biological Bulletin* since 1917. Professor Bach, working on catalase, had never heard of Burge. The Institutes of Tropical Medicine and Microbiology are ignorant of all the articles that have appeared since 1919 in the *Journal of Infectious Diseases*, *The Journal of Parasitology*, the *Journal of Experimental Medicine*, the *Proceedings of the Society for Experimental Biology and Medicine*, etc. How can they avoid the most lamentable duplication of work—work that to them involves such costly effort, work at the expense of the finest energies of the nation? How can they build with us, bricks on our bricks, as they ought to?

On the other hand, the Russians, too, are getting results that we should not be ignorant of. Each of the institutes mentioned holds meetings and publishes one or more journals in its lines: *The Progress of Experimental Biology*, *Bulletin of the Institute of Experimental Biology*, *Russian Eugenics Journal*, *Science* (all these edited by Koltzof); *The Progress of Physics*, *Bulletin of the Institute of Physics and Biophysics* (edited by Lazaref), etc., etc. In addition, the institutes and universities publish various other books and separate articles—such as Savadovsky's on sex, Smorodintsef's on enzymes, Barikin's on typhus. I have brought back samples of such periodicals and articles and will be glad to lend them to any scientists interested.

Something should be done to end this state of mutual ignorance. In the first place, in the interests of scientific brotherhood and of science itself, we ought to make our journals accessible to the Russians, for reading at least. The sending of just one or two subscriptions of each journal in its line to that center in Russia which would be most directly concerned with them would scarcely make a noticeable impression on the funds of any American scientific society. At these centers the journals could reach a large proportion of the people interested in them, owing to the peculiar centralization of Russian science in the research institutes. In addition to the sending of journals by societies, I would also urge members to send individual reprints and back numbers of journals. It is most important that these journals should get to exactly the right place—to those centers which do the work in question; for

this purpose they may be sent directly by mail to the appropriate addresses, of which I have published a list in *Science*, April 20, 1923. To be certain to avoid import duty they may be addressed to the institute, instead of to individuals as such.

In the second place, it will enrich our science to know of the foreign work, and we ought to let the Russians know that our journals are available for them to publish in. They are desirous of publishing here, for they see in America now the most important country in which science has been able to retain its old virility undiminished, and our recent biological work is held in the highest admiration. Thus, it would be deemed by any Russian biologist a most valuable privilege were he able to have his results incorporated in our journals with the body of American science.

And there are other media of scientific intercourse besides journals and books. It is remarkable how much just a little personal contact can effect. And it is touching to see how a people so long isolated absorb and cling to each casual word of information which a visitor may let fall. Better than articles, discussion and friendly talk can hit exactly the crucial spots. In illustration of this, I may mention the visits to America in 1920 made by Professors Vavilov and Jaczewsky, which have already resulted in a great rapprochement. But in order to enable these men to obtain permission to travel—from the governments of the countries directly concerned, as well as from those of the countries along the route—it was first necessary for them to receive a formal invitation from a recognized scientific body. In this case the invitation had been issued by the American Society of Phytopathologists to attend the convention of that body, and in view of this invitation the necessary visés were securable. These trips have already had a pronounced effect, which I was able to sense when I was in Russia. For Professor Vavilov, for instance, on returning to his country, had made a special tour throughout the land, giving numerous illustrated addresses to interested audiences of thousands of persons on the scientific work in America. And, on account of this, wherever I went, I found certain general viewpoints and salient features of our American research already familiar, even though the investigators might not have had a chance to read a single American paper. Based on these precedents, further visits might easily be arranged in similar manner by other societies. Various other Russian scientists have been mentioned above who would cover a very different field from that of Vavilov and Jaczewsky and whose talks would be of the utmost interest to us. It is to the advantage, not only of the Russians, but also of ourselves, for us to do what we can to encourage the visits of such men to this country.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson
Science Service, Washington

THE SUCCESS OF A FAILURE

"No," said the lumber dealer, "your boy is good for nothing in my business. In fact, he is the most miserable failure I have ever seen and will never amount to anything."

"Well," replied the disappointed father, "since Emil is too stupid to make a living in lumber, I suppose I might as well let him go to college as he wants to."

So Emil Fischer went to Bonn University to study chemistry. Here he was recognized as one of the most brilliant and industrious students in the laboratory and by the time he was twenty-three he had discovered a key that unlocked one of the most mysterious processes of life. This key was a coal-tar compound known to chemists as "phenyl hydrazine." It was both fortunate and fatal to Fischer. It made him one of the most famous chemists in the world and it brought him disease and death. For the fumes of it are poisonous and constant working with it ruined his health.

But nothing could impair his energy or dampen his ardor. For after he got free from the lumber business and started on his own track, he pursued it for forty-five years without interruption or diversion. As one of his colleagues said at the time of his death in 1919:

> A life is ended in which there was no failure, no let-up in restless activity, no long groping about for something to accomplish. After one quick, clear vision of the goal the path led straight to its accomplishment, a chain of brilliant successes.

How Professor Fischer himself looked at his life work is shown by these words:

> Still more enticing to some, among whom I include myself, is the hope to climb up out of the valleys to those passes seen afar off, which lead to vast and as yet unexplored countries.

The unexplored country that he had in view and ventured in was no less than the formative functions of vegetable and animal life. With the aid of phenyl hydrazine he was able to solve the secret of sugar. Not content with finding out how sugar may be made by the plant, he learned to make it himself. He found it possible to produce in the laboratory many more kinds of sugar than can be discovered in nature. Finally, he worked out a process by which he could start with plain coal and water and build up a series of edible sugars.

Then Fischer tackled a still more difficult problem in nutrition, the constitution of the proteins. These form an essential part of our food since they contain the nitrogen necessary to all life. It used to be thought that the proteins, whether of vegetable origin like the gluten of wheat, or of animal origin like the casein of milk, were much alike, and that it made little difference which of the many we got in our food. But Fischer showed that a protein molecule was made up of a long chain of carbon and nitrogen compounds and that the links were of very different kinds. Finally, he made a sort of artificial protein, what might be called a laboratory beefsteak, but whether it was good to eat or not could not be determined since there was so little of it and it cost so much. He spent $250 for the material alone, to say nothing of his time in constructing this compound, so, as he said, "It has not yet made its appearance on the dining table."

There is little prospect that the

THE STERLING CHEMISTRY LABORATORY OF YALE UNIVERSITY

One of the world's largest and best-equipped laboratories was dedicated on April 4, in connection with the annual meeting of the American Chemical Society at New Haven.

food of the future will come from the laboratory instead of the field. Even a professor of chemistry can not live as cheaply as a cornstalk. But the work of Fischer on the sugars and proteins has already been of immense value to the world in leading to the newer knowledge of nutrition which is already being applied to the feeding of stock and people.

As Sir Henry Roscoe, professor of chemistry at Manchester, said of Fischer when he was awarded the Faraday medal: "His name has the sweetest of tastes in the mouth of every chemist." Fischer conquered for chemistry a field formerly claimed by biology. He brought within the reach of experimentation what had been regarded as the exclusive province of vital processes.

So it seems that a man may be a miserable failure as a lumber merchant and yet make a success of something else. The problem of education is to fit square pegs into round holes without whittling them down too much in the process of schooling.

THE SUN CURE

OLD Tut-Ankh-Amen, who figures so prominently in our daily press, was brought up as a unitarian sun-worshiper, but later relapsed into the priestly polytheism, which was a pity, for if a people must pick its god from natural objects, as the Egyptians in their blindness had to, it is better to take the sun than to adore cats, crocodiles, hippopotamuses and beetles. The sun is quite literally the source of our vital and mechanical energy, the sole support of all life and motion on the earth, as the ancient Egyptian hymn declares, and we are beginning to recognize, perhaps I should say re-recognize, that it may cure diseases too.

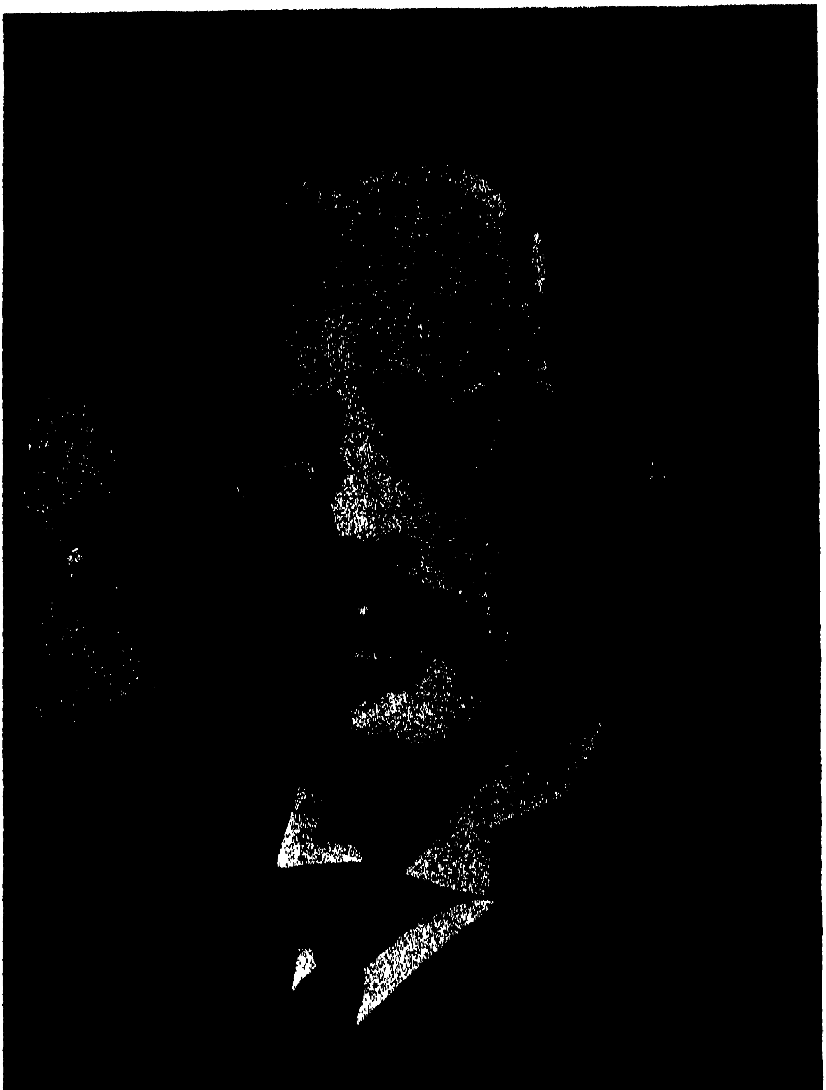
For man has a poor memory. He forgets much that previous generations have learned. The Romans used to make great use of the sun for the healing of sores and the maintenance of health. Pliny, in writing about how his aged friend, Spurinna, keeps his youthful vigor, says:

> When the baths are ready, which in winter is about three o'clock and in summer about two, he undresses himself; and if there happens to be no wind, he walks about in the sun. After this he puts himself into prolonged and violent motion at playing ball; and by this sort of exercise he combats the effect of old age.

But we northern races, having to wear thick clothing and stay in warm houses, get out of the habit of exposing our skins to sunshine. The invention of window glass led us astray, for glass lets through all the light that we can see, and we did not realize that it is opaque to the invisible ultra-violet rays which have the strongest effect upon the skin for good or ill. We thought if we had fresh air and sunlight (even though strained through glass) we had all that we needed from nature.

The rediscovery of the curative power of direct sunshine came by accident. In a hospital for rickety children, it was found that the child who had the luck to lie in a certain cot exposed to the rays of the sun recovered with amazing rapidity. Thorough experimentation, first on white rats, later on children, proved that rickets could be cured either by sunshine or cod-liver oil. There is no question which remedy the children will take if they have their choice.

Dr. Rollier set up a sanitarium on the sunny Alps of Switzerland where the children work and play all day in the sunshine almost naked, and he reports remarkable cures of tuberculous bones and skin troubles. Similar establishments for heliotherapy have since been started in England and America. The treatment of the patients is begun with two minute doses several times a day and increased by two minutes daily for a fortnight, with protection for the eyes and head. It is necessary to avoid both chill and sunburn. Thin white cotton cloth does not seriously shut out the curative rays.



SIR JOSEPH THOMSON

The distinguished British physicist, now master of Trinity College, Cambridge, who has been lecturing in the United States.

The aim is to get the skin tanned without being burned. Brunettes fare better than blonds. It seems that the curative effects do not come into play until the skin is well pigmented by exposure. No tan, no cure. When the skin of the greater part of the body is exposed to the direct rays of the sun, blood pressure falls and respiration diminishes in rate but increases in depth, so the volume of air inhaled is greater. Sunshine striking the skin expands the capillaries and brings more blood to the surface. The number of white and red corpuscles increase and these promote the healing process. The best results are obtained when the skin is exposed to the unfiltered radiation from the sun and yet kept from overheating by a light breeze or bodily movement. In our winter rooms we get the reverse of this, overheating and no radiation.

If sunbathing becomes a fad, it will put the police into the delicate position of having to determine in how far a coat of tan is a proper substitute for clothing.

POWER FROM PRICKLY PEARS

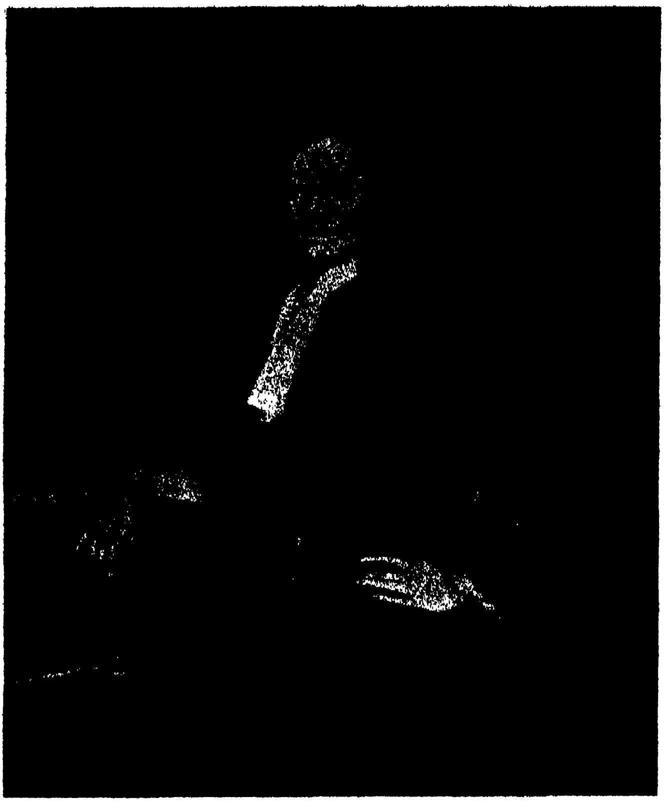
FROM South Africa comes the encouraging tidings that freedom from the petroleum power may come from the pesky prickly pear. It seems that a farmer in the Orange Free State, who had the misfortune to be infested with the cactus scourge, conceived the happy idea of converting his curse into a blessing by fermenting the fruit into motor fuel. Finding his formula worked he supplied samples of the fluid to his neighbors who used it in their cars and tractors with such satisfaction that the project passed to the stage of public demonstration and selling stock in the Mother Country.

It is stated that land bearing a good thickly thorny crop of prickly pears will yield twenty tons of the fruit, and that every ton of pears can produce thirteen gallons of alcohol. To this is added denaturants and a third of a gallon of an unspecified chemical. Since there are 2,000,000 acres of fertile land infested with prickly pear in South Africa, it is easy to figure out that the annual output of motor fuel should be 350,000,000 gallons, and since South Africa uses only 12,000,000 gallons there would be an abundance to export. And since gasoline costs $1.30 a gallon there and the new fuel is to be sold at 45 cents a gallon, it is a short jump to the claim that "there's millions in it."

To be sure, certain difficulties occur to the reader. For instance, who will gather the fruit from the cactus thicket? It is answered that they will be gathered "at a nominal cost" by the negro children who are very fond of them. But if they are like other children, their ardor for fruit-picking will diminish as their appetite is satiated. I imagine it will be a long time before we hear the wife of the rancher in our own arid region tell the children to "run out and pick a few bushels of pears so your pa can go to town on Saturday."

But whatever the difficulties the process is possible and it is to be hoped that something of the sort will prove profitable. South Africa has to import her gasoline and is already resorting to a substitute called "Natalite," from Natal where it was first used. It is essentially a mixture of alcohol and ether. The ether is manufactured from alcohol and is added to make the fuel more volatile and easier to start from the cold. Natalite, not too offensively denatured, might prove very popular in America as a mixed drink if secretly circulated among our booze-imbibing fashionables at high enough price.

America was most richly endowed with petroleum on the start, but it is a migratory mineral and we lost a lot of it in our haste to get it out and wasted a lot more in our haste



From a Painting by Sir Godfrey Kneller.

SIR CHRISTOPHER WREN

The great English architect, the two hundredth anniversary of whose death has recently occurred. Sir Christopher, who was also a distinguished scientific man, having been Savillian professor of astronomy at Oxford and succeeding Newton as president of the Royal Society.

to sell it. Some day we shall have to resort to a substitute, such as alcohol, which is grown as it is used. In fact, alcohol motor fuels are already coming into use and would be more common if it were not for the restrictions that have to be imposed at present to prevent their use as a beverage. It is to be hoped some way may soon be found to make the legal limitations less bothersome and expensive and at the same time sufficiently strict to insure that the alcohol gets into the carburetor instead of into the stomach.

If so, we may find a use for all sorts of waste materials, including perhaps the prickly pear, though this is not so serious a plague as it is in other lands to which it has been accidently or intentionally exported. In Australia it has multiplied like the rabbits and forms inpenetrable jungles over millions of acres. The government there will lease you 5,000 acres for ten years for a rental of one peppercorn a year, if you will only clear the land of its cactus.

Cactus of all kinds is exclusively an American invention, most ingeniously adapted to resisting drought and warding off eaters. It is not found anywhere else on earth except as it has been carried from this

Drawn by Harry Fenn.

HAMPTON COURT

One of the historical English buildings, of which Sir Christopher Wren was the architect.

country. If you see it in the desert scenes of a biblical movie, you will know that the picture was filmed in Hollywood instead of in the Holy Land, unless perchance the plant has invaded Palestine in recent years.

The world feels a grudge against America on account of the cactus. It is a thorn in the flesh of foreign nations. If now they could make motor fuel from it and so get even with the oil trust, which they also blame us for, they might feel better toward us.

DO THE PAPERS LIE ABOUT SCIENCE?

PROFESSORS as a rule have a poor opinion of the press. They are apt to think that editors are not merely regardless of the truth of the scientific "stories" they print, but that they publish by preference the most absurd and sensational stuff to be found. It is a common faculty saying about newspaper science that "what is new is not true and what is true is not new." It is also a common complaint in pedagogical circles that the newspapers do not pay much attention to science anyhow, that what little they do publish is antiquated and unreliable, and altogether unworthy the notice of educators.

But it has occurred to two scientific men to apply the scientific test to the prevalent opinion of scientists and see whether it is true or false. Or, rather, to find out to what extent it is true and false, for to the scientific everything is relative and must be measured.

The place where this experimental method was tried was, as we might anticipate, the experimental school of Teachers College, Columbia University, called the Lincoln School, which, although a new institution, has already exploded several scholastic fallacies.

The school has now another such scalp to its credit, for its director, Otis W. Caldwell, in collaboration with Charles W. Finley, has just reported the results of their statistical study of "Biology in the public press," which shows that scientists, in this field at least, have less reason to complain than they thought they

had. Fourteen prominent papers in as many different cities from Boston to Los Angeles were taken for a month and all the articles dealing with biological topics were clipped and classified.

The number of biological articles found during the month was 3,961, and of these only 14 are classed as "fictitious." Four of these appeared in one paper (San Francisco). Of the others, two at least can not be regarded as serious and deliberate attempts to deceive. One is a humorous account of a hoodoo black cat on Halloween and the other tells of a rooster who had been named Harding and taught to smoke cigarets. But I have known very strange things to happen on Halloween, even on the campus, and I have been told by a reputable scientist of a rooster that would eats cigarets, and surely chewing tobacco is as hard as smoking it, especially when one is toothless.

Fortunately the fakes are short. There are 25,596 inches in the total and the fictitious matter only measures 48, so that according to space, one would have to read on the average 500 inches of newspaper biology before he would strike an inch of fiction. Not, of course, that the biologists are willing to O. K. in detail all the other 499 inches. But they say that "gross misstatements of fact were not common," and on many of the dubious points there was room for honest differences of opinion. As for its being antiquated stuff, Messrs. Finley and Caldwell affirm that "newspapers appear to be more up-to-date in things biological than are college and high-school texts in the subject," and in conclusion they turn tables on the teachers by advising them to make use of newspaper articles in classroom instruction, in order to show that biology "is meaningful to the student." The professional nature faker is going out of fashion.

SCIENTIFIC ITEMS

We record with regret the death of Edward Williams Morley, professor of chemistry at Western Reserve University from 1869 until his retirement as professor emeritus in 1906; of George Lincoln Goodale, professor of botany at Harvard University from 1873 until his retirement as professor emeritus in 1909; of Alice Cunningham Fletcher, assistant ethnologist of the Peabody Museum, Harvard University, since 1882, and of Sir James Dewar, the eminent British chemist.

The University of Pennsylvania, at a special convocation, conferred the honorary degree of Doctor of Science on Sir Joseph Thomson, master of Trinity College. Sir Joseph, after concluding his lectures before the Franklin Institute, returned to England on April 14 on the *Homeric*.

The Willard Gibbs Medal of the Chicago section of the American Chemical Society has been awarded to Professor Julius Stieglitz, of the University of Chicago, for his researches in organic chemistry.

Professor Albert Einstein, of the University of Berlin, delivered three lectures in French at Madrid during the first week in March. The King presided at a sitting of the Academy of Science at which Professor Einstein was elected a member.

THE SCIENTIFIC MONTHLY

JUNE, 1923

A WORKING MODEL OF THE TIDES

By Professor W. M. DAVIS

HARVARD UNIVERSITY

A NUMBER of years ago when Dr. Isaiah Bowman, now director of the American Geographical Society of New York, was one of my students, he made under my supervision a working model of the tides, which ought to have been described at that time, and which, as the real tides are still running, deserves description even at this delayed date. The model consisted of a zinc-lined box, about 5 feet square and 10 inches deep, along one side of which the border of a continent was built up of clay and cement with a relief of 6 or 8 inches, so that an ocean, occupying the rest of the box to a depth of 5 or 6 inches, might lap upon the continental slope and mark its shore line. Hanging from springs and dipping into the ocean on the side of the box opposite the continent was a piece of plank which we called the plunger; by raising and lowering it slowly in a 5- or 10-second period as desired, undulations were produced which ran across the ocean and impinged like tide-waves[1] upon the continent, where, on being modified by the varied configuration of the shore line, they imitated a variety of tidal phenomena. The imitation was not a mere analogy but a true homology, for the tides are in reality nothing but a series of waves of small vertical range, of large length from crest to crest, and of 12 hour 26 minute period, which run ashore from whatever part of the ocean their source may lie in.[2] In the open ocean their vertical range is unknown, but it must be small; the range is increased as the waves run from a deep ocean into the shoaling water of a continental margin, and the form of the magnified waves is

1 The term, tide-wave, is used here in order to avoid confusion with the term, tidal wave, which has unfortunately come to be applied to earthquake waves.

2 See "Illustrations of tides by waves," *Journal of Geography*, iv, 1905, 290-294.

then further modified according to the pattern of the shore line. All these features were nicely imitated in the working model.

The configuration of the modelled continental margin and its embayments is roughly shown in the accompanying figure, in which the submarine contour lines have vertical intervals of about half an inch, which may be taken to represent several hundred feet in the real ocean. An inch in the diagram represents about a foot in the model, and 20 or 30 miles on a continent. No attempt was made to give the land surface a reasonable form; the pattern of the shore line was the important factor. Short threads or floats, attached to the bottom, serve to show the tidal currents; the tidal rise and fall can be measured on vertical gages divided into inches and fractions, and set up at various points as needed. A long stretch of simple outer shore line, ABC, trending somewhat obliquely to the approach of the open-ocean tide-waves, allows the tide to pass along it in the order of the letters. Attention should be first given to the tide on such an outer shore line because it there exhibits some of the most characteristic, and at the same

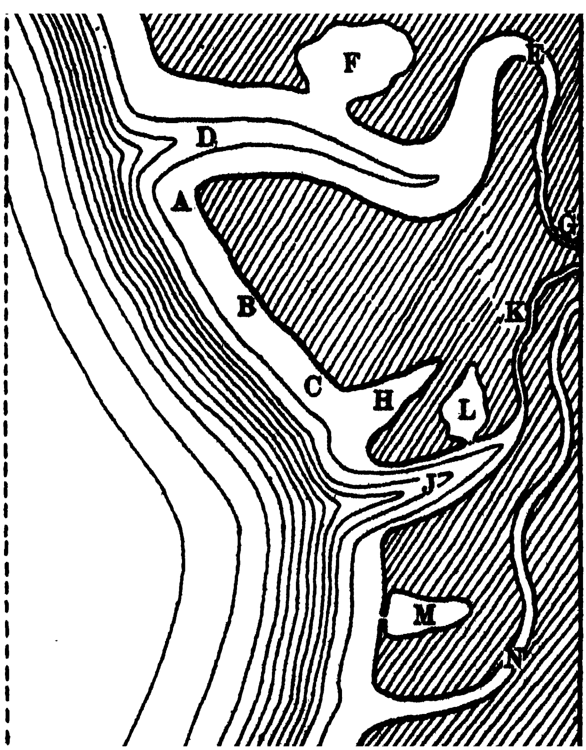


DIAGRAM OF A CONTINENTAL BORDER FOR A TIDE MODEL. Scale, about an inch to a foot. Submarine contour interval, about one half inch.

time some of the least generally understood tidal phenomena; namely, the occurrence of high water not at the end of the run of the flood current, but at about the middle of that run, when it has the greatest velocity; and conversely, the occurrence of low water at about the middle of the run of the ebb current, and at the time of its greatest velocity; while rising slack water occurs at about half height between low and high water, when ebb changes to flood; and falling slack water at about half height between high and low water, when flood changes to ebb. Such is the normal relation of these tidal elements.

If the rise and fall of the plunger be so adjusted that the vertical range of tide upon this simple stretch of the outer shore is half an inch, the horizontal range of the alternating flood and ebb currents may well be as much as 2 or 3 inches. Any one who sees this combination of vertical and horizontal movements and realizes that, when combined, they produce an orbital movement in the water, will be prepared to understand the relation of the vertical and horizontal movements of the actual tides on a simple outer shore line. The orbits will be perceived to be long flat ovals, in which the flood current is the forward movement in the upper half of the oval, and the ebb current is the backward movement in the lower half. Evidently, high water, which is produced by the rise of the water to the top of its orbit curve, must be at the middle of the run of the flood; and low water must similarly be at the middle of the run of the ebb. In actual tides on an outer shore line, the vertical range may be only a few feet, while the horizontal range, that is, the run of the flood and the ebb currents, may be almost as many miles. Hence in the orbital movement of the ocean water where a tide passes along a simple outer shore line, the horizontal diameter of the orbit may be several thousand times as great as the vertical diameter.

No one who learns this feature of the tides—and it is, as above stated, one of the most characteristic features of the tides on an outer shore line—will fail to understand that flood and ebb currents are just as essential tidal phenomena as, and indeed are much larger phenomena than rising and falling water. And no one who learns this feature from its simple exposition in a working model will have any trouble in understanding that, on an outer shore line of simple pattern, the rise of the tide from low water to high water takes place during the last half of the ebb and the first half of the flood; and likewise that the fall of the tide from high water to low water takes place during the last half of the flood and the first half of the ebb.

The manner in which these currents combine in order to produce changes of ocean level may be understood after one observes that high water does not occur at the same time all along the continental margin. If the stretch of the outer shore line, ABC, be made long enough to exhibit a high tide at C when the next following low tide is at A and the intermediate falling slack water is at B, attentive observation will disclose the explanatory fact that at the moment when the tides are so disposed, the water between B and C is moving, as part of a flood current, toward C; while the water between B and A is moving at the same moment, as part of an ebb current, toward A. Hence as the water on either side of the slack point, B, is moving away from that point, the water at the slack point must be falling, in preparation for the low-water phase of the tide-wave which will soon arrive there. On the other hand, when a high-water phase is at A and a low-water phase is at C, the water is moving toward B from either side, and hence the slack water there must be rising in preparation for the arrival of the next high-water phase.

A long, narrow and shoaling bay, DEF, indents the continental coast. It may represent such actual indentations as Delaware and Chesapeake bays. The high-tide wave may be watched as it enters the bay and runs up it; and one may then note that high water occurs later and later at points farther and farther inland, that the rate of advance of high water up the bay becomes slower and slower as it advances into shallower and shallower water, and that the vertical range of the tide, perhaps increasing at first, then decreases to smaller and smaller measures as the bay head is approached. With the slower advance of high water in the bay, the distance from one high water to another, that is, the length of the tide-wave, diminishes. One may also discover that in this bay the relation of the flood and ebb currents to high and low water and to the two slack waters gradually departs from the normal relation which they held on the outer coast, ABC, until, directly at the closed head of the bay, the slack waters coincide with high and low water, the flood current runs up from low water to high water, and the ebb current runs down from high water to low water. Such is the special relation of these tidal elements at bay heads.

By constructing shoals of various depths and breadths along the bay sides, the unlike dimensions of tidal flats for tides of similar range may be exhibited. By opening a shallow, half-tide embayment on one side of the main bay, as at F, a minutely rippling rush of rising tide will advance over it, like that which takes place on a vastly larger scale in the Bay of Mont St. Michel on the

northwestern coast of France. If the main bay be long enough, the tides may be reduced to a hardly perceptible range at its distant head. If, instead of being closed at its head, the bay there receives a river, GE, down which a gentle current of water runs from a faucet at G—a compensating outflow being provided in an escape pipe at one end of the ocean—the combination of river current running down-valley and of the tidal wave running up-valley may be examined. Experiment is here needed to determine a satisfactory relation of river current and tidal oscillation.

A small bay, H, will exhibit very clearly at its inner end the special bay-head relation of rising and falling tide and flood and ebb currents just described for the larger bay, DF, where that relation will not be well shown if a good-sized river, GE, opens into the bay head. Tidal currents will be relatively weak in the small bay, and must be inconspicuous at its head. It is presumably because most persons who look casually at the tides see them at or near bay heads that the special relation there obtaining between the rise and fall of the tide and the weakened run of the flood and ebb currents has come to be regarded as the normal and general relation; but in reality the normal relation is, as explained above, that exhibited on the outer shore line, ABC. It is, furthermore, very likely because harbor tides are ordinarily seen by casual observers that the vertical change of level has come to outrank the horizontal currents in the popular estimation of tidal phenomena. To be sure, change of water level and hence change of depth in harbors gives the vertical range there a practical importance in navigation which greatly exceeds the leisurely run of the tidal currents in such situations; but in coastwise navigation a little way off shore, where depth is sufficient even at low tide, the run of the currents is more significant than the tidal rise and fall. For example, as schooners can not sail very close to the wind they may find it necessary to anchor if wind and tidal currents are both unfavorable and wait until the current slacks and changes; then, with the current in their favor, beating against the wind is possible. I have seen a fleet of over 70 east-bound schooners thus lying at anchor in Nantucket sound while the wind and current were both against them; but as soon as the current changed, they all heaved anchor and set sail, making their way eastward around Monomoy point against the wind and then as fast as possible northward along the harborless outer side or "back" of Cape Cod.

If the small bay, H, be of appropriate configuration, the tide may increase slightly toward its head, instead of diminishing as at the head of the long bay, DE. And if a bay have a configuration

like a pouch or funnel, well opened and fairly deep at the mouth, as in bay J, the swashing oscillation of a standing wave, instead of the undulation of an advancing wave, may be produced in it, Such an oscillation will have an exaggerated vertical range at the head of the bay, as is the case in the Bay of Fundy. In a standing wave of this kind, it should be noted that high water is not much more delayed at the head than at the mouth of the bay, but occurs almost simultaneously all along the bay length. If the exaggerated high tide at the bay head enters a river, K, it will produce a tidal bore, or rushing wave of translation, rolling over and foaming at its front as it hurries up the river channel and rapidly fills it to high-tide level.[8] The fall to low tide is more gradual. Hence a river bore causes high water to occur nearer to the preceding than to the following low water.

Another bay, M, of moderate size, constricted at its mouth by sand reefs between which only a narrow inlet remains open, will have a reduced range of tide as compared with the adjoining outer shore line or with neighboring open bays; but it will have also greatly accelerated tidal currents rushing alternately in and out through the narrow inlet, in their unsuccessful effort to give the bay as great a tidal range as that outside. The trouble is that they have not time, in the short period of the tides, to do what they try to do. It may be noted that, if a bay of this kind still bears around its shore the marks of high-water wave work done before the sand reefs enclosed the bay mouth, such marks must stand somewhat higher than the diminished reach of high water since the enclosure of the bay; and an observer on discovering this discrepancy and not understanding its origin might conclude that a slight elevation of the land had recently taken place there. But if the observer be acquainted with Johnson's principle regarding the relation of the changes in shore lines made by waves and tides to the changes imposed on the tides by the changing shore lines, he will perceive that the discrepancy between the former and the present reach of high tide in the bay is not the result of an elevation of the land, but simply, as above intimated, of a local reduction of tidal range in the bay by reason of the formation of sand reefs across the bay mouth.

By adding a small bay, L, with a narrow entrance, at the side of the pouch bay, J, and making the bottom of the side-bay entrance about at half-tide level, the in-and-out currents there re-

[8] Good pictures showing the great range of tide in the Bay of Fundy and of the bore in the Peticodiac River, which enters the bay at its head, are given in the *National Geographical Magazine* for February, 1905.

sulting from the strong rise and fall of the tide in the pouch bay, will act like a reversing cascade, such as occurs on a rocky ledge at the entrance to the harbor of St. John, New Brunswick. Finally, a long river, N, may exhibit more clearly than the shorter river, GE, the interaction of river and tidal currents, the diminution of tide-wave length, and the gradual extinction of the tide up stream. If the river be long enough, two or more high tides may be seen advancing up it at the same time. If the mouth of such a river is somewhat funnel-shaped, the entering tide may take the form of a moderate bore, but less pronounced than that produced where the pouch bay, J, leads up to the river, K.

It has been tacitly assumed thus far that the beds of the rivers, GE, K and N, lie a little below mean sea level so far as they are included in the model; in that case the "head of tide" will not be distinctly marked. Let the bed of river, N, therefore, have a slightly increased slope, so that it rises above sea level about three quarters way up stream from its mouth to the model side. A well-defined contrast will then appear between the slender stream, which is fed from a faucet at the margin of the model and which runs in a trickling current down the upper quarter of the channel as a true river, and the much larger water course which, backed up from the ocean, occupies the lower three quarters of the channel and sways back and forth with the tides. Many of our Atlantic rivers exhibit this marked change of size at the head of tide. Down stream from that point the river becomes an estuary. Although the volume of water discharged from such an estuary to the ocean is little more than that received by the estuary from the true river at head of tide, the volume of water moved in the tidal currents of the estuary is immensely greater than the river discharge.

One thing more: when the tide-waves are working on the outer shore and in all the bays and rivers, it should be noted that, however much they are changed in wave length, in rate of progress, in range and in force, their period, that is, the time between the passage of two high tides at a given point, remains unchanged: it is everywhere the same.

Nearly all the tidal phenomena here described were well illustrated in our working model, but some of our efforts were not wholly successful. For example, we tried to construct an island in the large bay of such form and dimensions as to admit a tide-wave around each of its ends, so that there should be a point behind the island where the two tide waves, travelling unlike distances, would arrive with opposite phases and thus neutralize each other, producing a no-tide node of unchanging level. Such a no-

tide node was predicted by Whewell for the North Sea and afterwards discovered at a point where two tidal waves, one entering by the Straits of Dover on the south and the other coming around Scotland on the north, meet and counterbalance each other. There is little question that, had our experiments been continued a little longer, a no-tide point could have been produced. Another tidal feature that we wished to illustrate but did not realize is that of accelerated currents in a strait, like Hell-gate between New York harbor and Long Island sound. In this case a tide-wave arriving from one extremity of a long island produces high water at one end of a short strait when the corresponding tide-wave arriving from the other extremity of the long island produces low water at the other end of the strait: a strong gradient is thus produced in the strait and as a consequence the water rushes through it, first one way, then the other, whirling and eddying as it goes. The original whirling currents of Hell-gate have been greatly diminished by blasting away the rock ledges that formerly obstructed the channel.

There is another manifestly possible development of the model that we did not attempt; that is, a combination of two plungers driven by clock-work with slightly different periods and ranges, so that the one of longer period and greater range makes 13 oscillations while the one of shorter period and smaller range makes 14 oscillations, thus illustrating the luni-solar tides. If the plungers were hidden behind a curtain or screen, it would be an interesting problem for an attentive observer to determine the periods and ranges of the tide tide-making forces by studying the variations of the little tides on the imitation continental shores. Whether it would be worth while to complicate the movements of the plungers still further so as to exhibit the diurnal inequality of the tides must be left to some willing experimenter.

What the real and lasting value of a working model of this kind may be remains to be determined. Perhaps it will have to be included in that long list of laboratory devices which one teacher uses and which his successor discards.[4] Indeed, our tidal model was merely an example of those contraptions which one and the same teacher uses for a time and then abandons, because of lack of time or because of redistribution of emphasis in the course of his teaching; for that was the fate of the model above described. But if a working model of this kind were made for the gallery of a public museum, and on so large a scale that the ocean area should

[4] It is to be feared that this fate has overtaken a number of the pieces of geological apparatus recently reported to H. F. Cleland from various laboratories and described in his article, "Demonstration material in geology," *Bull. Geol. Soc. Amer.*, xxxiii, 1922, 56-85.

have a width of some 10 feet and the continental border a length of 15 or 20 feet, it would surely attract the attention of many visitors, if for no other reasons than that it would be a going concern. The movement of its floats and current-threads and the rise and fall of the water surface on its graduated gages would stop the casual visitor, and after stopping, he might really look closely to see what is going on. The plunger that actuates the tide waves should be concealed, as it would otherwise take too much of an observer's attention. It is said that the number of visitors to a museum of mechanical models in London was greatly increased when, from being merely stationary exhibits, they were made to "go."

But if a working tidal model is set up in a museum, one thing is certain; it ought to have a series of what are known as question-labels set up around it, by which an observant visitor shall be led to find out for himself the nature of the phenomena that the model illustrates. If only a mere name-label were on such a model, it would have very little value. How often, indeed, does one see visitors in a museum look at a name-label, and upon thus learning the most artificial part of the exhibit, walk away with hardly a glance at the thing that is named! Let me emphasize this point by the case of a museum exhibit of a group of anthropoid skeletons.

Below each of the skeletons in such an exhibit one ordinarily sees a name-label; a scientific name, to be sure, but nothing more. Yet each skeleton shows many more facts than its name; and the facts about the skeletons are best learned by observation, not by reading name-labels. It may be said, of course, that the skeletons are in plain sight, directly before the visitor; and that if the visitor wishes to see what the skeletons are, he has only to look at them. But this overlooks the patent fact that most visitors to museums do not know how to look at the exhibits; and that, even if they look, they do not really see much of what they look at. Thousands of visitors pass groups of anthropoid skeletons in various museums, and hardly one in a thousand of them consciously sees the extraordinary facts which the skeletons expose. Would it not therefore be worth while to attach to such exhibits a few question-labels, running somewhat as follows:

Does any one of these skeletons possess a bone that is not represented by a similar bone in all the other skeletons?

Which skeleton has the heaviest or the lightest bones in proportion to its size?

Which skeleton has the largest bone surfaces for the attachment of muscles?

Which skeleton therefore seems to represent the strongest being?

Are the skeletons arranged in order of inferred strength?

In which skeleton are the arms of greatest or of least length in proportion to height?

If the arms were straight and the skeletons were erect, how far down the legs would the finger tips reach in each of them?

Are the skeletons arranged in order of relative arm length?

In which skeleton does the arrangement of the big toe bones in the foot most nearly resemble that of the thumb bones in the hand?

What differences in habits of walking and climbing do these differences of bone arrangement suggest?

In which skeleton does the profile from the top of the head to the mouth, as seen from one side, slant at the lowest or the highest angle?

In which skeleton is the chin most retreating, most square, most pointed?

Compare the angle between the forehead profile and the chin profile in the different skeletons.

Are the skeletons arranged in order of forehead-chin angle?

In which skeleton does the skull appear to afford the least or the greatest space for the brain in proportion to the total size of the skeleton?

Are the skeletons arranged in order of relative brain space?

Which skeleton probably represents the least intelligent or the most intelligent being?

What animals and what races of mankind are represented by the skeletons?

The essential feature of these questions is that they direct attention to significant facts which are as a rule overlooked by undirected attention, and which are nevertheless easily discovered by conscious attention. And it is to be remarked that not until these significant facts have been discovered by observation should the name-labels of the skeletons be referred to. The names may then serve their proper purpose of verbal handles with which to pick up packages of observed facts, instead of serving, as too often happens, the improper purpose of masks which discourage or even impede the observation of the facts. With such question-labels as aids, a group of anthropoid skeletons or any other similar exhibit in a museum might be looked at intelligently by perhaps 30 or 40 visitors in a thousand; and at least those 30 or 40 would then carry away an instructive mental impression regarding a certain number of definite things, instead of only a confused and vague memory of a vast number of half-seen or less-seen things.

A working model of the tides in a museum should likewise have a carefully prepared series of question-labels around it. The questions might be graded to advantage; some being of an elementary nature, adapted to school children; others being more advanced, adapted to adults. Experiment as to the usefulness of the question-labels could be made by showing them and removing them in alternate months, and comparing the attention given to the model with and without their aid. Some sample questions for adults are here suggested:

What is the time interval between the moments of successive high waters at A or B or C? (Note. This can be best determined by measuring the total time of ten or more high-water intervals, and then dividing the time by the number).

What is the change of water level or vertical range between low water and high water at A or B or C? (This may be measured on vertical gages a little off shore, on which inches and fractions are marked).

Describe the horizontal movements of the water, or tidal currents, associated with changes of water level at A or B or C. (The currents may be shown by little moored floats or by threads attached to the bottom a little off shore).

How far does the water move in these alternating tidal currents? (Scales of inches and fractions should be marked along the shore at various points).

What is the average velocity of each current?

At what time in the run of each current is its velocity greatest?

Estimate the velocity at that time and compare this greatest velocity with the average velocity.

Describe the relation of the alternating horizontal currents to the rise and fall of the water surface. (Note. The current that is running at the time of high water is called the flood or flood tide; at the time of low water, the ebb or ebb tide. The brief time when the currents cease running in order to change direction is called slack water).

What is the relation of rising slack water to ebb and flood?

Answer the same question for falling slack water.

(The progressive advance of successive tide-waves or high water up the large bay, DE, having been brought out by appropriate questions): How much later is high water at the head of the bay than at its entrance?

What is the average velocity of high-water advance up the bay?

Compare this velocity with that of the tide-wave crest as it crosses the open ocean. (Note. Several vertical gages, divided into inches and fractions near the water surface, should be set up in a line across the ocean to show its changes of surface level as the tide-wave advances).

(Appropriate questions having been asked as to the range of tide at the mouth and head of the pouch bay, J.): Compare the time of high water at the mouth and the head of the bay.

Compare the movement of the water in this pouch bay with that in bays DE and H.

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(In case a double plunger is constructed to show the luni-solar tides): Observe 30 or 40 successive high waters at A or B or C. How much does their range vary?

In how many tidal periods is the variation of range accomplished?

Assuming that the stronger tides result from the added action of two periodic tide-producing forces, and that the weaker tides result from their opposed action, what is the relative value of the two forces? What is the period of each force?

These sample questions suffice to show that a great variety of instructive exercises upon the facts shown by the tide model may

be provided. But they show also, as in the case of the anthropoid skeletons, that the exercises can be properly solved only by a painstaking observer; and that even such an observer will lose much time unless he is guided by the question-labels. It is of course true that few visitors to a public museum will care to give the time, or will have the time to give, that is demanded for the plodding progress along the true plebeian road to such learning as is here afforded; but those few will be repaid for their patience and persistence.

It was, indeed, with the object of using our working tide model in teaching the tides that it was first constructed in the basement below my laboratory by Dr. Bowman, as intimated above; but the practical difficulties of carrying out an informing and disciplinary exercise on the model, in systematic association with the routine of class and laboratory work, proved difficult and discouraging. The model could not be exhibited during a lecture, partly because of the small dimensions of its phenomena, still more because its level water surface could not be seen by an audience of seated students. Only a few students could examine the model at the same time even in the laboratory; hence in a class of 80 or 100 members, 10 or 15 sections would have had to take their turn, and each section would have needed at least half an hour—better, an hour—to solve the assigned questions. The labor of arranging the times at which so many sections could examine the model appeared to be greater than the profit they could get from it. Yet it has always been a regret that such observational work on the model could not have been introduced as a regular part of laboratory exercises while the lectures on tides were in progress; for the model would then have provided a basis of fact, even though only imitative fact, on which the theory of the tides could have been expounded. Perhaps some more energetic teacher may accomplish this desired result.

But in spite of the difficulties in the way of making practical use of the working tide model in teaching, such a working model may still have a high value as a museum exhibit; and this article is written chiefly in the hope that it may encourage museum directors to try the experiment of constructing a tide model and running it by clock work, so that it shall always be going and ready for examination by such visitors as care to examine it. Let it be remembered, however, that a series of question-labels is just about as important as the periodic plunger in bringing the model up to its real value as an instructive scientific exhibit. A working model of this kind, in the presence of which the should-be

observer remains passive, is hardly worth its cost or worthy of its space. Its value will not lie in the work that it does, but in the work that the museum visitor does upon it; and as such work should be of a thoughtful and systematic and disciplinary kind, its performance is not to be expected without the aid of question-label guides. It is my belief that if museums had many exhibits such as groups of anthropoid skeletons or working tide models, each with appropriate question-labels, the public would gain more instruction from them than is now the case.

DISEASE AND HEREDITY

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AT the present time there is a widespread interest in all problems which relate to heredity, and the ramifications of these problems extend into very diverse fields of social as well as individual life. Yet it is only a relatively short time since the public in general became acquainted with the question of heredity, the first impetus in this direction being due perhaps, more than anything else, to the influence of a modern writer, Henrik Ibsen, who very powerfully, although from a scientific point of view incorrectly, first presented on the stage the tragic consequences of the heredity of disease.

In any discussion of this subject, it is essential first to have an understanding of the meaning of the terms "disease" and "heredity." To define heredity, we must go back to the carriers of heredity; and these are the germ cells—the egg in the case of the mother, the spermatozoon in the case of the father. Both of these cells contain what is called the germ plasm, which really constitutes the sum of all hereditary factors. The germ cells, after having united, or, expressed in a different manner, after fertilization has taken place, develop into the embryo and in the full grown individual, and the character of the germ plasm, which partly comes from the mother and partly from the father, determines what kind of an embryo and what kind of an individual shall be produced. At an early stage of development the fertilized germ cells give origin in the embryo to new germ cells, which later become the germ cells of the individual—egg in the female, spermatozoon in the male. Thus in successive generations the germ cells form one continuous series, the united parent germ cells giving rise to a next generation of germ cells in the offspring; and because one generation of germ cells is derived directly from the preceding generation, therefore the germ plasm, of which the germ cells are the depository, is transmitted continuously from generation to generation. It is this continuity of the germ plasm through endless generations which is the basis and cause of heredity in living organisms, plants, animals and man.

Now we have said that an individual has the same structure

and functions as the parents, because in so far as the germ plasm is the same in both; but while this statement taken in a broad way is correct, it needs in reality certain modifications. The character of the germ plasm is indeed the main factor which determines the structure and functions of the fully developed organism, but the germ cells themselves need for the display of their power the constant interaction with environmental factors. These latter may be situated within the developing individual, when they represent an inner environment; or they may be situated in the outer world and then they represent an outer environment. The environmental factors include the common conditions upon which our life depends, such as light, heat, oxygen and foodstuffs; but there are also specific environmental factors which the germ plasm needs in order to be able to produce specific structures and specific functions. Some of these environmental factors can be varied and sometimes even eliminated experimentally without endangering the life of the individual as a whole, while others are relatively constant and unchangeable and necessary, if life and development are to proceed. It is well to insist upon this interaction of germ plasm and environment in order to understand the significance and the limitations of heredity in disease. If the germ plasm is normal and if the environmental factors are normal, a healthy organism results. But if the germ plasm, which in reality is made up of a multitude of individual units, if this germ plasm or the environmental factors are abnormal, then disease results.

We spoke just now of the germ plasm of an organism as being composed of a multitude of individual units. Part of these were passed on to the offspring from the father, part from the mother, and their combination determines how far the individual resembles the father and how far it resembles the mother. But there may be in the offspring characters which have not been visible in either of the parents, because in the latter they had been hidden. Such factors, hidden in the parents, but appearing in the offspring, are called recessive unit factors, and for a recessive factor to become manifest in the child it is necessary that both parents carry it latent in their germ cells and that it thus be present in double dose in the child. On the other hand, it is possible for a unit factor to become manifest in the offspring, although it has been received from only one parent, as this factor tends to dominate, as far as manifestation is concerned, over the parallel unit factor in the other parent, and such factors are called dominant unit factors. Thus, for instance, a dark eye-color as a rule dominates over the blue eye-color. Sometimes unit factors, and in particular some of those which determine certain diseases, are

coupled with other unit factors which determine whether the offspring shall be a male or a female. In this case a disease may appear, for instance, only in the male members of a certain family; yet it is transmitted by the females, although in the latter it is not manifest, because the unit factor or factors upon which the disease depends is recessive. Such a disease would be due to what is called the sex-linked recessive type of heredity.

From what has been said, we may easily reason out that as far as heredity is concerned there are three possible classes of diseases: (1) In the first place, the germ plasm of an individual may be normal and therefore have a satisfactory hereditary endowment, but certain injurious influences attack him from without, and cause either directly or indirectly a disturbance in the structure, composition and functioning of the organism. Such injuries might, for instance, be due to the action of excessive heat or cold, to the absorption of certain poisons or to the entrance of microorganisms. Diseases thus produced are entirely the result of environmental factors. (2) There is a second class of diseases which result from an altered constitution of the germ plasm. These are necessarily of a hereditary character because, as we have seen, the germ plasm is transmitted from generation to generation. But as the germ plasm interacts always with certain environmental factors, strictly speaking the latter enter also this class of diseases as a component cause. However, then, environmental factors are common needs in life processes in general, they are constant and fixed and are not susceptible of alteration, and they are, therefore, not really causes of such diseases in the sense in which heredity is the cause. (3) In the third class of diseases also the germ plasm is altered in an injurious direction; but in this case the change is of a more delicate nature and it requires, in order to become manifest as disease, the cooperation of certain environmental factors, which are variable; they can be diminished or increased or may be entirely eliminated and the disease varies in a parellel manner. In certain cases an individual with an injured or somewhat abnormal germ plasm may be practically normal under a healthy environment, but if a surplus or a deficiency of environmental factors, which in a person with a healthy germ plasm would be without injurious consequences, should affect them, disease would result. In this third class, then, we have to deal with diseases in which both germ plasm and environment enter, but in each disease the alterations of the germ plasm and the character of the environmental factors, which are responsible for the disease, vary.

It follows thus that in order to define the significance of heredity

in a given disease, we have to answer three questions: (1) Is the disease due to environmental factors, or to changes in the germ plasm, or to both these factors? (2) If both factors enter, how much is due to each, and what are the environmental factors which come into play? (3) If heredity plays a part, wherein does the change in the germ plasm consist and what is the character of the hereditary transmission? Are the disease-producing factors recessive or dominant? Are they sex-linked or do multiple factors underlie the condition? Now, at the present time our knowledge is not complete enough to answer all these sets of questions; the character of the hereditary transmission and the changes in the germ plasm leading to disease in particular are doubtful in many cases, owing to the difficulty in analyzing sufficiently the various matings in which a weakened germ plasm becomes manifest. As far as practical consequences are concerned, the most important problem for us is how much of the causation of disease to attribute to an altered germ plasm and how much to environmental factors, and in particular what are the environmental factors which are responsible for the resulting inferiority. In this respect our knowledge also is as yet incomplete.

So far we have stated the principles which apply to the study of heredity in disease. We shall next review, very briefly, the part heredity plays in disease. A few diseases will be cited as examples of the different types of heredity in their relation to environment, in order to illustrate our preceding more general remarks. But before doing so, it might be well to state distinctly that not every case of transmission of disease from parent to child is of a hereditary character. If, for instance, the parents suffer from an infectious disease, like syphilis, and the child shows signs of syphilis at the time of birth, this merely means that the same microorganism which invaded the parent was transferred from the body of the parent to the body of the child, and thus the same disease from which the parent suffered was produced in the child. The disease in such a case is therefore not due to the transmission of a faulty germ plasm—and it is the latter condition alone which constitutes hereditary transmission—but it is due to an infection.

If we observe carefully a large number of individuals, we find that some of them admit of a classification into certain types according to their bodily and perhaps even their mental characteristics. These types represent what has been called the constitution of a person. Thus there has been distinguished an asthenic or weak type, a muscular or athletic type and a stout or pycnic type. Other types have also been observed. Now, some of these types lead to disadvantages in the process of living, but in particular it

has been noted that certain bodily structures or constitutions predispose of specific diseases. But what is of special interest is the observation that, in many cases at least, these constitutions are inherited and with them the tendency to certain diseases.

And not only this tendency is inherited, but it even seems that the duration of life itself depends upon a hereditary factor. Statistical studies in man indicate this conclusion, as well as experimental studies in certain insects. (Pearson, Pearl.) This, of course, does not mean that the duration of life is definitely predetermined in each individual; it merely means that among the various factors which do determine the length of life, heredity is one factor, for environmental conditions interact with heredity and largely influence the end result.

Now, if we pass over to the diseases proper in which heredity comes into play, we may mention in the first place certain malformations, due to so marked a faulty development of the embryo that visible abnormalities in bodily structure result. Supernumerary fingers and toes, hare-lip, cleft palate, pigmented moles and abnormal generative organs may be cited as examples. It is of interest that such rather crude malformations depend almost entirely upon hereditary factors. They are essentially due to the faulty reproduction of normal developmental processes, as those which normally lead, for instance, to the formation of fingers and toes in the young, and both the malformation and the development of the normal structure depend in the main on the character and the function of the germ plasm and are largely independent of variations which might occur in the environment. In certain cases, however, a malformation may be due to injuries received in the uterus, and in a few instances heredity determines only a part of the diseased condition, the full consequences of the change in the germ plasm becoming manifest only under the influence of external conditions acting in later life.

In a wider sense all hereditary disease or tendencies thereto are due to deviations in the structure or composition of the developing organism. In most cases these deviations are of a finer, more delicate character, not visible to the naked eye; but malformations in a strict sense represent, as stated above, rather crude, visible deviations from the normal.

One of the best studied classes from the viewpoint of heredity is diseases of the eye. Various errors of refraction, such as short and far sightedness and astigmatism, represent essentially hereditary alterations or malformations in the structure of the eyeball. Cataract is one of the common causes of blindness. It may appear in the young and then it is entirely due to heredity; or it may

appear in old people, and formerly it was thought that in the latter case cataract was due to environmental injuries, accumulating during many years of life; but it has recently been found that even in the typical cataract of old age, heredity plays an important part and that perhaps external injurious influences make the hereditary tendency merely manifest. We see here an example of apparently similar diseases being due to different causes and thus in reality representing different diseased conditions, and similar instances of this kind may be found in various other classes of diseases. Among other diseases of the eye due to heredity is night-blindness, and this condition has been traced in certain families from generation to generation for several centuries. Thus in some English families which suffer from this disease, all the cases can be traced back to a common ancestor in France, who himself suffered from night-blindness. A rather frequent disease of sight, in which the mode of hereditary transmission has been determined accurately, is the common kind of color-blindness. Here the hereditary character to which the disease is due is sex-linked and recessive. It is usually transmitted to the male offspring through the women, who themselves may be free from the disease. There are many other diseases of the eye, due to heredity, or in which at least heredity plays a part, but there are also other diseases of the eye which are due in the main to external factors, as, for instance, infections.

It will be interesting to contrast with malformations and diseases of the eye in which, at least in many cases, heredity plays the larger part, a class of diseases in which, on the contrary, the importance of environmental factors is quite evident. This is true of the infectious diseases, such as diphtheria, tetanus, smallpox, tuberculosis and many others. While undoubtedly external factors are dominant in these diseases, and no disease of this kind is possible without a preceding infection with the specific microorganism, yet even here inner hereditary factors play a certain part. Thus, it has been observed that certain acute infectious diseases may take a very much more severe course when they are first introduced among a new population hitherto not exposed to the disease. When the disease has once been established among a certain group of people, it seems to take a less virulent course and this probably indicates the influence of certain constitutional factors among that population, which possibly are of a hereditary character.

A good example of the action of hereditary factors in infectious diseases is found in tuberculosis. It has, for instance, been observed that this disease takes a somewhat different course in different families of guinea pigs and that this difference remains con-

stant in successive generations. In the human race the large majority of all children become infected with tuberculosis at some time in their life, but usually the disease takes a very light course. Upon this early infection the tuberculosis of adults may be superimposed. Now it has been found that constitutional factors of a hereditary character in a certain measure determine the disposition of an adult to fall prey to a tuberculous infection, and, moreover, hereditary conditions in association with variations in the mode of infection and in the virulence of the microorganisms largely determine the severity of the infection and the course the latter takes. In particular, individuals of an asthenic type, with a flat, narrow chest, are at a great disadvantage if tubercle bacilli gain an entrance in their body; yet not only hereditary factors, but also weakening environmental conditions may cause a predisposition to this disease.

A very well-investigated disease as far as the relative significance of environmental and hereditary factors is concerned, is found in tumors and in particular in cancer. If we briefly summarize our knowledge in this respect, we may state that some varieties of cancer are almost exclusively due to hereditary inner causes. In other kinds a combination of inner hereditary factors and of environmental stimulating factors is responsible for the disease; and still others are caused exclusively or almost exclusively by external conditions and here heredity plays apparently no or only a negligible rôle.

There are large classes of other diseases affecting our inner organs, as, for instance, the digestive system, heart, kidneys, thyroid gland, blood-forming organs and blood-vessels, and nervous system, in many of which heredity plays a more or less important part; but the significance of heredity varies greatly in different cases. Even in the same kind of disease a certain form may be mainly due to hereditary factors, while in another very similar form environmental injury is apparently of greater significance. Thus, in diabetes, as it is seen in young persons, a hereditary factor seems to be preponderating, while in the diabetes of older persons environmental factors play a much greater rôle than in younger persons. Certain kinds of goitre are mainly dependent upon the constitution of the germ plasm, while in other cases toxic substances or infections are responsible. In gout heredity plays a great part, and outer injurious conditions call forth the attack in predisposed persons. A very striking example of heredity is seen in hemophilia, the disease of bleeders. Small injuries, like cuts, may lead to long-continued bleeding, uncontrollable by ordinary means. This is an inherited disease; usually only men are

thus affected, but the disease is transmitted to the male offspring by the women. In this case we have therefore to deal with another example of sex-linked, recessive heredity. The disease can be followed through many successive generations, and it has been possible to trace families in this country to bleeder families in Europe.

From a social point of view perhaps the greatest importance attaches to the heredity of mental diseases. Mental abnormalities alter fundamentally the personality and social relations of the diseased person. A number of mental diseases are essentially due to environmental factors, as, for instance, progressive paresis, which is caused by the organism of syphilis, the spirochæte pallida. Syphilitic infection may in addition cause other mental disturbances, and the infection of the parents may be responsible for feeblemindedness in the offspring. Certain kinds of epilepsy likewise may be caused by environmental factors, such as injury. However, many kinds of mental deficiencies are to a great extent due to a hereditary abnormality of the germ plasm. Among these we might include certain varieties of feeblemindedness and idiocy. In a number of cases the history of families affected by such deficiencies has been traced back through successive generations, and there were found associated with feeblemindedness in various members of the family alcoholism and a tendency to criminality and to sexual excesses. While in such cases we have probably to deal with a combination of hereditarily transmitted tendencies and a very unfavorable mental environment, acting from early life on, yet the deficient constitution of the germ plasm is the predominating factor. Some of the most important mental diseases proper are largely due to hereditary changes in the germ plasm. This applies to the manic-depressive insanity in which melancholic and inhibited states or maniacal and elated states occur, or in which both of these alternate; it also applies to dementia præcox or schizophrenic insanity, which occurs mostly in younger persons and which shows very variable symptoms. In paranoia proper and in hysteria inherited tendencies likewise play a great part. Some of these inherited tendencies to mental diseases seem to be associated with definite bodily constitutions which are thus also inherited; and moreover certain mental patterns and temperaments which still fall within the range of the normal or are at the borderland between the normal and the diseased, and which are the equivalent of corresponding types of inherited mental disease, seem likewise in certain instances to be associated with these special bodily constitutions. We see in this case, as in others which we might have mentioned previously, a continuous transition be-

tween the inheritance of disease and of analogous normal characters, and both are due to the same underlying causes.

While thus in many cases of mental disease and deficiency there is no doubt as to the great significance of heredity, yet we must not therefore conclude that environmental factors, as, for instance, upsetting mental experiences, the effect of poisonous substances, play no part whatever in the origin of these inherited diseases. This latter possibility can not be disregarded at present, and it is impossible to foretell to what extent even hereditary diseases and deficiencies of the mind might not be prevented or mitigated, if we were able to provide a suitable mental environment, especially adapted to their needs, to predisposed persons from early years on.

The rapid survey of diseases in their relation to heredity, which we have now made, though it is of necessity very incomplete, suffices to indicate how important is the rôle of heredity in disease. The number of diseases in which heredity has been established as a cause is already to-day extremely great; yet we shall probably not be much in error if we foresee a still greater extension of their number as the chances for investigation become greater. We have also seen that there is, in very many instances, an interaction between heredity and environmental factors in the origin of disease. The relative importance of hereditary and environmental factors, in those diseases in which both act in association, differs greatly in different cases and it is not correct to speak in a general way of the significance of heredity or environment in inferiority and disease; each case must be analyzed separately to determine the part played by either of these two sets of factors.

Having now established the great importance of the hereditary constitution of the germ plasm in the causation of disease, we may inquire whether it is possible to make any statement as to the origin of a diseased germ plasm. At the present time we know positively of two conditions which may alter it in such a way that disease results in the organism, and in addition there is at least a possibility of a third condition: (1) The first well-established cause of a diseased germ plasm consists in the appearance of mutations, sudden changes in the composition of certain parts of the germ cells, in some cases at least due to a loss of a particle of the germ plasm. Such mutations, which are hereditary, are responsible not only for diseases, but also for other sudden changes in the constitution of an individual which still fall within the range of the normal. Mutations not only lay the foundations for a certain disease in the developing organism, but in some cases they cause the death of the fertilized egg before it has had a chance to develop fully. These latter mutations depend upon the introduc-

tion of so-called lethal factors. Mutations and in particular the appearance of lethal factors have been most thoroughly studied in the fruitfly, Drosophila, where the investigations of T. H. Morgan and his associates have led to a far-going analysis of the constitution of the germ plasm; yet the occurrence of such lethal factors is not restricted to Drosophila; they have been found also in higher animals. The causes for the appearance of mutations are not known at the present time. (2) The second class of causes underlying a diseased germ plasm is of an entirely different character. While in the case of mutations we are at the present time not aware of any influence due to external or environmental factors, the causes now under consideration consist entirely of injurious influences exerted by the outside world. Through the very extensive experiments of several investigators, among whom we may cite especially Stockard, it has been shown that if we expose animals, as, for instance, guinea pigs, for a long period of their life to a very pronounced action of alcohol, the offspring in successive generations will show definite inferiorities as to fertility and bodily vigor, although the members of these later generations have themselves not been exposed to the influence of alcohol. In some cases even malformations may appear in the offspring, especially malformations affecting the brain or the eye. These inferiorities may be transmitted by an alcoholized father as well as by an alcoholized mother; and not only the bodily characteristics are thus altered, but the mental capacity has been found to be diminished also, as in rats, the grandparents of which had been alcoholics. (MacDowell and Vicari.) However, it may be in certain instances that the action of alcohol, by weeding out the weakest germ cells, may actually lead to the survival of relatively strong individuals (Pearl). There is some ground for believing that other poisons, particularly lead, may act in a manner similar to alcohol. We may even consider the possibility that other unfavorable environmental factors, bodily or mental, may have a certain injurious effect on the germ plasm, provided they act through a very long period of time; yet, while we may consider such a possibility, we must be aware of the fact that an actual proof of such an effect has so far only been given in the case of certain poisons. (3) The third class of causes for the deterioration of the germ plasm is still under investigation at the present time. There is some indication that not only a general deterioration may be brought about through the action of toxic substances, but that, in addition, specific toxic substances or other specific interferences affecting a certain organ may cause such a change in the germ plasm that in the offspring similar defects in that particular organ,

and only in that organ, appear without interfering otherwise in the general condition of the individual which may remain normal. Such experiments have been made within recent years by M. F. Guyer, who produced experimentally defects in the eye of rabbits which were apparently transmitted from generation to generation. Of a similar character are possibly certain disturbances of equilibration in rats which have more recently been studied by Griffith and Detlefsen. If in these cases a hereditary transmission of specific somatic deficiencies should be definitely proven, the significance of these investigations would be very far-reaching, not only as far as the origin of disease is concerned, but also as a proof of the inheritance of acquired characters in general.

There is still another way by which a hereditary deterioration of the germ plasm and an increase in hereditary diseases may be brought about, namely, through continued inbreeding. Breeders of animals have for a long time past believed and they still are of the opinion that long-continued inbreeding produces unfavorable results, as far as the fertility and vigor of the offspring are concerned. The experiments of Shull and East in plants as well as the recent experiments of Sewall Wright in the Department of Agriculture, in Washington, have on the whole substantiated this view. Likewise in the case of man it has been observed that in communities where much inbreeding occurred, the results have on the whole not been favorable.

While thus some undesirable results follow inbreeding, inbreeding as such does apparently not produce a change in the constitution of the germ plasm in the sense in which mutations or the actions of certain poisons exert such an effect. Its influence depends in the main upon the joining together in the offspring of the same kind of deficiencies which in the parents had been dormant as recessive characters. It may be expected that, if relatives marry, they possess in a certain number of cases the same kind of latent weakness. Being present in double quantity in the offspring, this deficiency becomes in the latter potent and visible. It follows that if the germ plasm of both parents is perfect, close inbreeding would not only lead to a deterioration, but should even tend to preserve the good qualities of the ancestors.

It is thus possible under special conditions to continue close inbreeding over long periods of time and still to maintain vigor and fertility unimpaired. Thus in rats Miss H. D. King has shown that a deterioration as a result of inbreeding can be avoided by always mating together individuals especially selected for their vigor and fertility. Crossbreeding between different strains and races may have a beneficial effect, at least in the first generation

of the offspring, provided the distance between the two individuals is not so great that incompatibilities between the germ plasm arise.

We have seen that both hereditary conditions in the germ plasm, as well as injurious environmental factors, cause diseases and that in many cases both sets of factors interact and in a specific manner in particular diseases. We may foresee that in the future we shall discover additional hereditary factors, where we had previously only seen environmental injuries and, vice versa, we shall learn of associated environmental injuries, where in the past we had only known of fixed hereditary causes. At least this is what may be expected, if progress should continue to make the same course it has taken in the past, and if we consider that environmental factors are often hidden and become discernible only through careful experimental analysis. Moreover, we have learned that inner conditions as well as outer environmental factors may change the hereditary constitution of the germ plasm. So far, we can not yet be sure as to the permanency of the changes which have been induced in the germ plasm through the outside. It is not impossible that gradually a recovery may take place from the deficiencies thus produced, and possibly the future will teach us that the germ plasm may not only be influenced through injuries in an unfavorable direction, but also that on the contrary improvements may take place through favorable conditions, although at present we have not yet any information as to the existence of the latter kind of changes.

Is it possible to make use of the knowledge of heredity as a cause of disease, bodily and mental, in the conscious direction of human affairs, so that what is best and finest in human life is preserved and aided in its development? We might attempt to accomplish this by selection of those individuals which are endowed with the best germ plasm and by the weeding-out of what we consider the inferior germ plasm. Such a weeding-out process might be done consciously—and the Spartans attempted something of this kind many centuries ago—or it might be left to the ravages of nature, disease and poisons, or of a struggling human society through the means of various kinds of warfare. In cases in which individuals possess very pronounced deficiencies, especially of a mental kind, we are justified in discouraging the production of offspring in the interest of the individuals themselves thus affected, as well as of their potential offspring and human society in general.

But if we consider a further going use of this weeding-out process, there are some objections of the most serious nature to the application of such principles for social betterment. In the

first place each individual represents a great multitude of inherited tendencies, and there is some justification for the belief that in the large majority of all persons there are factors present which favor the development of one or the other disease and of certain bodily or mental inferiorities or undesirable peculiarities. And not only the kind of tendencies, but also the intensity with which these tendencies act, varies in different cases. Each individual represents a composite picture of the most intricate kind, and most parts of these pictures are entirely unknown to us, as far as the individuals are concerned, and individuals are the only real units in existence; neither do we exactly foresee at the present time, in many cases at least, the result which would follow from the combination of various factors, for instance of those which from a social point of view may apparently be indifferent, with other apparently equally indifferent factors. We would be prone at the present time, in very many cases, to select a few obvious characteristics, especially those making for bodily vigor, to the detriment of finer, less obvious characters. And there is, furthermore, some suspicion that each individual or social group would value most highly those characters with which they believe themselves endowed.

Moreover, our knowledge of the relative importance of environmental and hereditary factors is very incomplete as yet in the range of the normal as well as in the range of disease. Our everyday assumptions in this respect are often misleading and this applies to the conclusions of the laymen as well as to the views of the writers in this field, if their views are not based on very carefully analyzed evidence. In some cases we are prone to attribute to external factors what in reality is due to heredity, but in other cases we fall prey to the opposite tendency, to hold inner hereditary factors responsible for what is really the reaction of the organism to certain environmental conditions, physical or mental.

Furthermore, these methods would involve a weeding out which means some kind of destruction. There is danger that we thus would introduce or accentuate in our social and mental environment exactly those characteristics which are unfavorable to a finer and better life. We should therefore proceed with the utmost caution in recommending an improvement of human society by the process of selection and weeding out of germ plasma.

Excepting the conditions mentioned above, it seems at the present state of our knowledge preferable to attempt an improvement by spreading through education a knowledge of factors which are well established in the hereditary transmission of normal and

diseased conditions and to improve environmental conditions in such a way that the germ plasm is protected against the action of injurious influences, physical as well as mental, and perhaps even improved through the action of favorable conditions, if this should be possible. Furthermore, through our increasing knowledge of the injurious environmental factors without which certain inherited weaknesses or tendencies are not realized—and we may expect that the various institutions for the study of heredity in man, which have been founded more recently, as for instance, the Eugenics Laboratory at Cold Spring Harbor, will enlarge our information also in this respect—we may more and more obtain the ability to direct the environment in a manner most suitable for the production of healthy individuals; and this would apply to mental as well as bodily conditions.

Even if by these means individuals should be preserved, which in a ruthless struggle of life would be weeded out, we can not be sure that the qualities which are thus saved are not worth more than the bodily strength and the particular mental characteristics which were lacking in such individuals and which caused their inferiority in the struggle of life as it is constituted at present. But on the other hand, we can be sure that by applying these principles, we do not introduce into our life warfare and antagonisms and fears, which in the end would tend to vitiate the value of the price we seek, the development of human character and personality.

ORIGIN AND EVOLUTION OF THE INSECTS

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BEFORE attempting a discussion of the subject it may be well to obtain a somewhat clear idea of what is involved. There are something like 400,000 described species of insects, and the total number existing in the world has been variously estimated at from one to ten millions, the former being the minimum. These insects occur in all parts of the world and under very diverse conditions. They swarm in the tropics, and mosquitoes are so abundant in the Arctic regions as to make existence at certain seasons almost unbearable. Grasshoppers flourish in the open, grassy areas, while our extensive woodlands are the favored haunts of thousands. The waters have been invaded and we find peculiar forms in pools, lakes and rivers. A number prefer the brackish waters of the salt marshes, a few occur in the saline waters of the ocean, some delight in the super-saturated solution of Great Salt Lake in Utah and one species is found in petroleum pools. Great variations in size occur among insects. The Hercules beetle of Venezuela measures some six inches in length. A Venezuelan grasshopper has a somewhat greater length and a wing expanse of nearly ten inches, while one of the fossil dragon flies has a wing spread of more than two feet. These giants present a striking contrast to the more minute insects, some of which are only about one hundredth of an inch in length and find the requisite sustenance for a complete life-cycle within the speck-like egg of the codling moth.

Insects live upon our highest mountains as well as in areas below sea level and it is noteworthy that those occurring upon extremely high mountains are closely related or identical with Arctic species. We are concerned in the origin and evolution of this vast assemblage and in order to arrive at a correct solution it should be considered in its broader aspects.

If we compare insects with some of the related forms, such as the centipedes and the crayfish, it will be found that they are all bilaterally symmetrical and are composed of a linear series of rings or segments, bearing paired, jointed appendages and agree in having an external skeleton composed largely of chitin. Furthermore, the internal economy of these divergent forms is very

similar, the dorsal blood vessel or so-called heart occupying an upper median position, the digestive system a central position and the nervous system a ventral, median position, the last in the simpler forms at least with distinct swellings or nerve centers for the various segments. The general prevalence of this type through a considerable series of animals indicates a relationship and a common origin, in the judgment of many naturalists.

Turning to the insects once more, we may note first of all the prevalence throughout this immense group of one million or more forms with the general characters mentioned above and if we examined individuals more closely, it would be found that they may be divided by less general characters into immense series, such as the bees and related wasps, the beetles, the butterflies and moths, the true flies, the true bugs and a number of other less extensive divisions. If we refer to competent authorities in some of these groups, it will be found that even in America there are some 10,000 different species credited to the bee family, over 10,000 beetles, nearly 10,000 of the true flies, nearly 7,000 butterflies and moths and a very large number of species of true bugs. This means that there are immense series of very similar insects, some of which can be separated from close allies only with difficulty, and yet in most cases the differences are sufficiently marked so that there can be no real question as to the specific identity of this large number of forms. That is, each one of this enormous number of species breeds true and will continue to exist as a specific entity unless it succumbs to some combination of adverse conditions.

It is possible to go a little farther and find among insects relatively large groups of species belonging to individual genera or nearly related genera, the different species approaching each other closely in structure and general habit and yet presenting sufficient differences anatomically or biologically, usually both, so that no question exists as to the distinctness of these various forms. One of the most striking cases is found among the large series of cutworms belonging to the genus Agrotis, as originally defined, and now broken up into several closely related genera. There is a series of nearly three hundred of these species, the adults of which approach each other so closely that only very few specialists are able to distinguish between the different forms, and yet there are marked variations in the larvæ or cutworms, both as to coloration and habits. A very similar condition is found in the May or June beetles. Some appreciate their general resemblance to each other, and yet a recent list includes 97 species belonging to one genus and having for the most part very similar habits. The striking, active, vari-colored, yet very similar tiger beetles are

represented in this country by 75 species and what has been said of the June beetles is largely true of these latter. We may turn, if one prefers, to moths other than the cutworms mentioned above and find large series of very similar forms. In some cases, at least, these variations are evidently of advantage, since they distribute the chief feeding period of different species through the season and thus permit a given amount of vegetation to maintain without excessive injury a larger number of insects.

Somewhat the same condition, though on a less extensive scale, is found among mosquitoes, which up to within comparatively recent times were supposed to represent a nearly homogeneous group. Careful studies have shown, however, that this is far from the case. There are large series of mosquitoes presenting marked differences in structure and in habits, and in certain cases mosquitoes which are separable from each other with great difficulty in the adult condition are easily differentiated in the larval or wriggler stage by both structure and habits. A survey of an entire group, such as the mosquitoes mentioned above, the much larger and brilliantly colored flower flies or the very minute and almost unknown gall midges, show wonderful variations in structure and habits among insects possessing much in common and undoubtedly closely related to each other, and in certain instances at least these variations may reappear in a number of distinct lines within the same family. Take the gall midges, for example; there are variations in the number of antennal segments from six to forty-one, in the number of palpal segments from four to one, in the number of tarsal segments from five to two, and in the number of wing veins from six to none. It does not surprise one familiar with insect life that such variations should occur. There is food for thought, however, in the knowledge that these deviations from the more primitive or simple to the more specialized and complex should arise independently in a series of related groups easily separated from each other by general and relatively immutable characters. These modifications either have some relation to each other or have resulted from some other cause, possibly creative acts. Acceptance of the latter explanation viewed from the standpoint of the entomologist, conversant with the immense series of insects and their numerous variations in structure and habit from a comparatively few standard types, involves the acceptance as the true explanation of something like a million special creations for insects alone, or the development of many of the minor variations from a smaller number of special creations. A belief in the progressive change from the simpler to the complex, extending over millions of years and comprehending in its ultimate application the immense variety of

animal and plant life occurring upon the globe at the present day, is only the logical development of the former.

The precise formulation of our belief in regard to the origin and development of the animal and vegetable kingdoms is in one way a matter of minor importance, since no belief seriously affects present conditions, though it may modify our attitude toward life in general. It must be admitted that these conditions have significance and inquiry would show that most naturalists find a thoroughly logical explanation in an evolutionary theory which accounts for these multitudinous forms as deviations from common types, these variations being traceable in class, ordinal, family, generic and specific characters. Certain changes are going on at the present time, though at such a slow rate and by such imperceptible degrees as to be unrecordable, excepting in some of the plants and animals, the cultivated and domestic, which have responded to artificial environments to such an extent as to vary greatly from the original or wild type. Such variations can not be denied. It is well known that differences occur among wild species and in not a few instances it has been possible to recognize individuals in the same way as we distinguish between individuals of our own race.

Variations within specific lines occur among insects as well as in other forms of life. One of the most striking and well established is the well-known alternation of generations in gall wasps, a divergence so marked that alternate generations up to within a few years were recorded as belonging to different genera. Somewhat the same conditions are found among certain plant lice, except that it is more usually an alternation in series of generations rather than individual generations. Many species of plant lice have winged and wingless individuals, the difference apparently being due to environmental influences. The well-known chinch bug has a short-winged as well as a long-winged form, both being associated at times. Some butterflies present well-known seasonal variations, the colors of the two generations being markedly different. There are frequently well-marked variations between the sexes in insects, these sometimes being very pronounced, and in certain variable groups there are more or less incidental structural variations in the right and left antenna and possibly in other organs. These are brought to attention simply to emphasize the fact that variations do occur among insects belonging to the same species and occasionally at least in individuals. It is probable that no two insects are exactly alike in the same way as among the larger animals.

There is no denying the host of relationships and resemblances to be found in the present-day insect world. The naturalist has

long since learned to accept resemblances with a great deal of caution, because investigations have repeatedly shown that structures apparently identical and modified in a similar manner are in reality very different. Because of this the investigator approaches his problem from more than one aspect if possible and it is, therefore, suggested that with the above in mind we turn to the evidence presented in nature's records, the fossils of earlier ages. There has been found, for example, in the lower Silurian of Sweden a single wing doubtfully referred to the genus Protocimex, a possible prototype of Cimex, an insect which laymen mention with bated breath as the bedbug. Can it be that this insect was an associate of Pithecanthropus? Next comes a wing of Palæoblattina from the middle Silurian of France and a possible forerunner of the cockroaches of to-day. This latter suggests a further insect approach toward subhuman association.

If our geologists are right, these forms were found upon the face of the globe millions of years ago. There are some, however, who question their belonging to insects. If this be granted (it is really not necessary), there has been found in the slightly more recent Devonian strata the print of an ancient May fly wing and the remains of another insect suggestive of the cockroach, a nearer approach to subhuman association, so that the postponement of our acknowledging the presence of insect life upon the face of the earth is, relatively speaking, a matter of minor importance. Next comes the carboniferous or coal strata with its host of insect forms, some plainly closely related to our modern cockroaches. There is no denying the insect character of these carboniferous fossils. More recent strata show the continuance of these and related forms, and finally in the upper deposits there are undoubted representatives of our modern insects. The progression from the oldest insect-bearing strata to the most recent shows a gradual though not necessarily continuous development from what we regard as the simpler and more generalized to the more complicated and specialized insects of the present day. In other words, the history of insect life as traced in the rocks corroborates and strengthens the conclusions in regard to the development of the various forms gained by a study of the species living at the present time.

Turning once more to a consideration of insects and their allies, we would reiterate the fact that there is a very large group or class possessing a number of common characteristics, the Arthropoda, the forms with segmented legs and for that matter in large measure at least with segmented bodies. This is true of the crayfish, the spiders and their allies as well as the centipedes and millipedes, each representing an important and distinct group of approximately equal rank with the insects, though the last named is much

more numerous in species. A close survey of these groups of Arthropods would disclose species here and there presenting structures approximately intermediate between these large classes, indicating that during the progress of time—that is, the passing of geological ages running into millions of years—there has been a gradual splitting off or divergence of types from ancestral stocks and that by this process through almost endless ages there has developed the exceedingly abundant and variable group known as insects.

We have heard much of late about the teaching of evolution. Those who have accepted this explanation of the varied animal and plant life upon this globe find their justification in the life around them. The evolutionary theory is in large measure an attempt to explain the numerous variations, not only in insects but in all animal and plant life—variations that are meaningless if one fails to recognize a general plan of development or reaction to environment, if one prefers that term. It is to be expected that the geological evidence would be fragmentary if one makes allowance for the many agencies which would normally result in the destruction of every vestige of organic life and only occasionally present conditions favorable for its preservation in the everlasting rocks. The wonder, if any, is that the record is so nearly complete and that it harmonizes so closely with the evidence which has been secured from studies of animals and plants throughout the entire world, especially of those forms which evidently show relatively little change from an earlier primitive condition.

Development, evolution is freely admitted in the progress of civilization, the perfection of human relations and human devices and the better adaptation of animal and plant life to human needs. No one thinks of apologizing for the term "backward races." It is freely admitted that these have not developed or evolved to the same high standards as the more civilized peoples. The existence of "backward individuals" is also recognized, though not "socially." Many of the more progressive peoples accept the blessings of civilization and carefully avoid all reference to earlier and more primitive types of existence and some in continuance of this attitude display a consistent hesitancy to the recognition of evolutionary processes which may be seen in all branches of the organic kingdom, provided one has learned to decipher the records of nature. The revolution of the earth was denied, the circulation of the blood challenged, yet both continue in obedience to fundamental laws which can not be declared unconstitutional and in time all may accept the broader truths underlying the theory of evolution and that without contravening their allegiance to matters spiritual.

FISHERIES RESOURCES IN PERU

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Introduction

THE Republic of Peru is entirely within the tropics, yet, owing to the effect of the cool Humboldt Current which flows northward in contact with its whole coastline, the littoral waters are of temperate rather than tropical character. This part of the eastern Pacific lies to the southward of the region of equatorial doldrums, and to the northward of the horse latitudes; it is marked, therefore, by equable, coastwise winds, and is without storms from one year's end to another. The continent is indented by a number of harbors suitable for the establishment of fishing bases, such as the bays, or protected roadsteads of Independencia, Chilca, Paracas, Callao, Ancon, Huarmey, Samanco, Ferrol and others. Finally, because of certain unusual hydrographic conditions, marine life is extraordinarily abundant. But in spite of all these favoring circumstances, there is not a single organized fishing industry along the twelve hundred miles of Peruvian shore line.

Primitive Condition of the Fisheries

Few littoral waters of the globe teem with fish and with other edible products as do those of Peru, and yet in no other enlightened country are fisheries more restricted to methods which, with one illegal and disastrous exception (*i. e.*, dynamiting), are such as the Indians have followed from immemorial times. The modern Peruvians are highly appreciative of fish food, but, with the wealth of an exceptionally productive ocean at their door, they import their stockfish from countries within the northern hemisphere.[1] The waterfront fish-stalls of Callao are, indeed, well patronized, and a considerable quantity and variety of fresh fish are distributed through the great public markets of Lima, the capital; but the price of all but a few kinds is so high as to be prohibitive to the majority of the inhabitants. Two species, the bonito and the anchoveta, may be classed as staples; for the rest, the greater part

[1] The only modern account in English of Peruvian fisheries is the following, which has been freely consulted in the preparation of the present paper: Coker, R. E.: "The Fisheries and the Guano Industry of Peru," *Bull. U. S. Bur. Fisheries* for 1908, Vol. 28, pp. 333-365, plates 12-17.

CABALLITOS, OR REED BOATS
Stacked on the beach at Pacasmayo.

of the aggregate catch in Peru is consumed in the communities of the Indian fishermen themselves, or in those of their more opulent near neighbors. In short, the coastal aborigines, continuing the customs of their ancestors, subsist upon a wide variety of sea products which comprise nearly all available kinds of fishes, as well as of molluscs and other invertebrates; the industrial landsmen of the seaboard towns utilize first the bonito and the anchoveta, and after these a limited number of dried or salted sea foods; while the well-to-do Peruvians confine their salt-water diet chiefly to a small selection of the most toothsome fishes, such as the flounders, corvinas and pejerreyes (silversides). The only shellfish which is commonly classed with such expensive delicacies is the scallop.

The present unsatisfactory condition of the Peruvian fishing industries, the fastidiousness of an important part of the population, the unequal utilization of sea food among the various classes of society, the relatively high cost of such food in the seaports and its extreme scarcity elsewhere, are all easily explained. They are due, in brief, to (1) certain underlying social and industrial causes connected with the former unstable economic condition of the Republic; (2) to the primitive methods employed and the lack of fish products plants of any description; (3) to the difficulties of transportation in a land of few railroads; (4) to the scarcity and high cost of manufactured ice; and (5) to the national, monopolistic control of the salt supply.

Native Equipment

The Peruvian fisheries as they exist to-day represent a some-

what decadent native system slightly influenced by Mediterranean methods. The vast majority of the fishermen are pure-blooded Indians, whose equipment is doubtless not greatly different from that of the days before Pizarro. Such modifications as are found have been introduced mainly by maritime settlers of Italian stock, who now more or less predominate in the fisherman's vocation at the important centers of Ancon, Callao and Chorillos. The ordinary *chalupa* or fishing boat of central Peru is, of course, a Mediterranean type of craft—a double-ended, seaworthy boat, of broad beam, with no centerboard and a clumsy sailing gear. The centerboard, which would be a device of particular usefulness in this region of constant coastwise winds and currents, is unknown in Peru. The chalupas are used in all branches of the line and net fisheries, as well as for dredging, and, in spite of their intrinsic shortcomings, they are so well fitted out with the necessities of sea life that they serve as reasonably comfortable homes for the fishermen during voyages which sometimes take them for several days far from land.

Other more ancient types of craft used in the Peruvian fisheries are the *balsa,* the *canoa* and the *caballito.* The balsa is nothing more than a raft made of the extraordinarily buoyant Ecuadorian wood of the same name. Sometimes balsas are large enough to transport whole families, with their possessions, and are equipped with sails; but the fishing balsas which one sees on the beaches or carrying heaps of fish to the stewards of steamers in the northerly seaports of Peru are usually small and unrigged. They are propelled by means of one or two broad plank-oars, which the fishermen thrust straight down into the water at the stern and use as levers against the ends of the logs.

The *canoas,* made of Ecuadorian hard wood trees, of which one called the *guachapelí* is the favorite, are dugouts with planked-up gunwales. Sometimes they are forty feet or more in length. They are seaworthy when well manned, and, because of the density of the timber from which the best of them are constructed, it is said that they have a life of a hundred years or more.

The *caballito* or "pony," so-called because the fisherman sits astride it, is a very remarkable native boat made of bundles of reeds lashed together. It is a wonderful craft in heavy weather, riding breakers like a Hawaiian surfboard, and it is at the same time a thoroughly practical fishing boat when manned by an experienced native. A large caballito may have a length of fifteen feet, but it is so light, unless water-logged, that a man can easily carry it on his shoulders.

In the way of fishing tackle, many kinds of seines, drag-nets

A RIGGED BALSA OR FISHING RAFT
Talara, northern Peru. (Photograph by Harry Watkins; courtesy American Museum of Natural History.)

and casting nets, hand lines, trawls, dredges, and grains or spears, such as are common to most parts of the world, are used by the Peruvian fishermen. The seines are of various dimensions and meshes, each sort taking its vernacular name from the fish for which it is particularly designed: thus "pejerreyera," a net for pejerreyes or other small fish; "bonitera," of the right mesh for the bonito; "cazonera," a net for *cazones* or large sharks. The casting net or *atarraya* is employed chiefly in the surf of sandy beaches, and is identical with those which I have seen in use among West Indian and Brazilian fishermen.

Destructive Methods

The Peruvian fishermen, not content with the simple but effective equipment of their native fishery, have unfortunately acquired a new and fearfully destructive means of obtaining larger catches with less labor, namely, dynamite, the *chinchorro americano* or "American net," as it is called with grim humor. The illegal use of this explosive, which is widespread at least in central and southern Peru, bodes ill for the future of the Republic's marine resources, for the havoc that it wreaks among schools of fishes, and especially of young fry which are not worth picking up, can not fail eventually to cause a profound depletion of many species. Quantities of dynamite are naturally imported into Peru for use in the mines. By one means or another much of it comes into the hands of fishermen, who detonate it under water when they wish to obtain either food fish or bait. It is used with the latter object,

for instance, when anchovetas are destroyed as "chum" to attract corvinas or other large fishes to the surface, after which a second charge can be set off. In all phases of the dynamite fishing the destruction of life is generally greater than could be utilized even if a good proportion of the fish were not inevitably lost through their failure to rise or to remain afloat long enough to be scooped into a boat.

Popularity of Sea Food

As indicated above, the fisherfolk of Peru scorn few if any of the marine invertebrates which occur in profusion along parts of the coast. Not only are scallops, oysters, mussels, whelks, crabs and lobsters prized, but, moreover, squids and octupuses, holothurians, ascidians, sea-urchins, chitons and the "sand-bugs" or hippas of the sandy beaches are all utilized in one form or another. The molluscs of Peru apparently furnished a considerable part of the food supply of the ancient Indians, as they do of their successors, for in graves among old burial grounds at Chorillos and Paracas Bay I found the shells of many species which are still sold in the fish markets of Callao.

Some of the molluscs which are valued for food are taken on the rocks, in the sand of the beaches, or on mud flats exposed by the falling tide, but scallops, oysters and *caracoles* (snails) are often obtained by dredging in relatively deep water. One mollusc which formerly promised to support a valuable fishery in northern Peru, and which may once again assume importance, is the pearl oyster (*Pteria peruviana* Reeve), the same species which is the basis of a pearl fishery in the Gulf of California.

Opportunity for Fish Product Plants

Upon visiting so rich a seacoast, any one with a knowledge of fisheries can not fail to be impressed by the unrealized opportunities for the development of desiccating, canning and packing plants in Peru. Aside from many available fish, and such species of molluscs as the giant mussel, which might be preserved for distribution in the same manner that clams are canned on the west coast of Florida, the bays of Peru abound in an unusual variety of large edible crabs, some of which are similar to the crustaceans upon which the Japanese have based their extensive export trade in crab-meat. Lobsters (*Palinurus*), related to those which the Chileans pack in tins at Juan Fernandez, are likewise common in parts of the coast. So far as I have learned, no sea food of any kind is canned in Peru, the only familiar native marine products being dried or salted fish of many sorts, pickled anchovies and preserved fish eggs and sea weed.

A DREDGING CHALUPA
Laden with scallops, Callao.

A CANOA, OR DUGOUT, AT CHUCUITO
The fishermen's beach of Callao.

Variety of Fish Life

Although the entire Peruvian coast lies well within the tropics, its shore fish fauna is in general of subtropical or temperate rather than equatorial character. The reason is, of course, to be sought in the conditions of oceanic circulation produced by the Humboldt Current. Peruvian fishes are, in a zoogeographic sense, comparable with Mediterranean fishes rather than with those of the Atlantic coast of America. In both Peru and the Mediterranean region we find an admixture of tropical species with others which are distinctly temperate or even northern, such as the *jurel* or scad (*Trachurus*). The closest faunal affinities of the Peruvian fishes are with those of the Californian littoral, which lies just outside the tropics in the northern hemisphere. Many species are common to both of these widely separated areas.

If we group the Peruvian fishes according to their environmental affinities, rather than their zoological relationships, we find aggregations of species adapted to all types of habitat that exist along the coast. Thus there are (1) many kinds of rockpool fishes; (2) numerous species specialized for life on rocky bottoms of greater depth, and (3) others, like the flounders and some of the rays, which are particularly characteristic of sandy bottoms and shallow water; (4) schooling, plankton-feeding forms, like the herrings and anchovetas, are impressively abundant, while these are pursued by a great variety of (5) larger predacious fishes, among which are the mackerels, barracudas and the free-swimming types of sharks. Only anadromous fishes, like the alewives and

salmon of North America, are unrepresented in the Peruvian assemblage.

IMPORTANT FISHES OF THE COAST

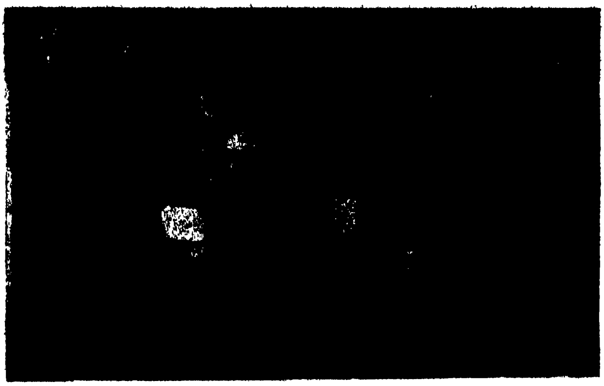
A brief consideration of a few of the more important Peruvian marine fishes, group by group, may prove of interest.

1. *Sharklike Fishes.* These include a score of species of dogfish, sharks, angel-fish, skates, rays and chimeras or ratfish. Certain representatives of these families are common in all parts of the coast, but it is in the north, near the point at which the Humboldt Current mingles with warmer equatorial waters, that the sharks, guitarras and rays are found in greatest numbers. At Lobos de Tierra and Lobos de Afuera Islands an important fishery is carried on by the northern maritime Indians, both the rays and the sharks, including hammerheads and other species up to seven or eight feet in length, being prepared as dried or salted products. So far as I learned, the valuable liver oil yielded by many of these fishes is seldom utilized. Neither are the hides saved, although, as has been recently demonstrated in the United States, they can be converted into superior leather.

2. *Herrings.* Of the three Peruvian species of herrings, the best known are the *sardina* (*Sardinella sagax*) and the *machete* (*Potamalosa notacanthoides*). Both of these migrate in enormous schools which sometimes fill the bays, supplying sustenance to larger fishes of more value to man, as well as to certain sea birds, and to the sea lions. On the calm morning of November 14, 1919, I crossed Pisco Bay when the shining surface, ruffled only by an occasional puff of wind, enabled me to obtain a clear view of such multitudes of herrings as I had never previously beheld. At one time I counted thirty distinct schools of *sardinas* within a quarter of a mile of my launch.

It seems probable that a Peruvian *sardina* fishery, conducted in the manner of the menhaden fishery, would prove profitable. The relative oil yield of the *sardinas*, as compared with menhaden, has not been determined, but it is altogether likely that several marketable products, including "kippered herring," oil, "fish guano," and an ingredient of cattle and poultry food could be derived from them. For the use last suggested, the dried fish-scrap might be combined with cotton-seed waste, of which there is always an unutilized surplus in the country.

3. *Anchovies.* This family is dominated by the anchoveta (*Engraulis ringens*), a fish not exceeding six inches in length, the most abundant and important fish of the entire Peruvian littoral, the mainstay of the bird guano industry, and a food fish of high rank. Like the sardina, the anchoveta subsists upon minute forms



ROCK FISH FROM THE BALLESTAS ISLANDS

Left to right: 1, "mulata" (*Pimelometopon darwinii*); 2, "babunco" (*Doydixodon laevifrons*); 3 and 4, "cabrilla" (*Paralabrax humeralis*); 5, "ojo de uva" (*Hemilutjanus macrophthalmos*); 6, "burro" (*Sciaena fasciata*); 7, "chavelita" (*Chromis crusma*); 8, "chita" (*Anisotromus scapularis*).

of plant life, such as diatoms and other algæ, and possibly upon small pelagic crustaceans. The fishes travel in schools of incredible size, the immature examples being sometimes visible as red dots among the massed adults. They are followed incessantly by larger fishes, sea lions and birds of very many species. Myriad numbers of the anchovetas, at least when conditions in the Humboldt Current are favorable, are likely to be found at any point along the entire Peruvian coast-line.

During the afternoon of February 2, 1920, while on board a steamer off Huarmey, I estimated that a hundred schools of anchovetas were within sight. At times, when the bonitos attacked them from beneath, large areas of the surface would be so broken by the leaping of the little fishes that the ocean hissed as though a deluge of rain were descending upon it. The most remarkable sight of all was the manner in which whole herds of sea-lions were lolling and frolicking among the anchovetas, gorging themselves to the limit of their capacity.

On other occasions I have had the good fortune to run directly over schools of anchovetas in a launch of shallow draft. Their appearance from above is amazing, for the quivering, silvery creatures seem to be packed together like sardines in a tin, except that their heads point all in one direction as their legion, which somehow seems more like an individual organism than a conglomeration of millions, streams through the gauntlet of its diverse and ubiquitous enemies.

The abundance of the anchovetas is indicated also in other ways, for it has been conservatively estimated that *thousands of tons of*

CHORILLOS, SUBURB OF LIMA
With fishing boats at their moorings.

these fishes per day are devoured by sea birds which breed in colonies of hundreds of thousands, and even of millions, on some of the Peruvian islands.[2]

The anchovetas have from early times been crudely preserved in Peru by mixing them with salt earth. Sacks of this dried product find their way far into the interior. The anchoveta would make a tinned product of excellent quality, but since the species is the principal food of the valuable guano birds, the question of granting a concession for an organized fishery would need thorough and unprejudiced investigation. It is probable, however, that the anchoveta occurs in great excess of the needs of the birds, across the entire width of the Humboldt Current; in any case, an almost unlimited modern purse-net fishery would be less disastrous for the species than the present practice of dynamiting.

4. *Flying Fishes.* These fishes, which are characteristic of warmer pelagic waters, well off shore, come into the Humboldt Current along with dolphins and other tropical species during the southern spring and summer (November to February).

The flying fish are not in themselves important food fishes in Peru, but their egg-masses are dried to form a product known as *cau-cau.*

5. *Silversides* (Atherinidæ). Of this widely distributed family, the small marine pejerrey (*Basilichthys affinis*), which, like the

[2] See R. C. Murphy: "The Guano Industry of Modern Peru," *Brooklyn Museum Quarterly*, Vol. 7, p. 259, 1920.

A LARGE TUNNY (*Germo Argentivittatus*)
Of a species sometimes common in the northern waters of the Humboldt Current.

anchoveta, occurs in great schools, is probably the most delicious eating of all Peruvian fishes.

6. *Mullets.* The *lisa* (*Mugil cephalus*) is a prized and abundant fish. Mullets of this and related species are often stranded in great numbers upon the mud flats of such inlets as Independencia and Paracas Bays.

7. *Mackerels.* The representatives of this family include two very important fishes, the *caballa* or common mackerel of the country (*Scomber japonicus*), and the bonito (*Sarda chilensis*). The latter, because of its abundance and cheapness, constitutes the foremost item of marine food among the poorer people of the whole coastal region. The *caballa* also supports a considerable fishery, being taken chiefly on hand lines. Quantities are salted at the Lobos Islands and elsewhere. The *caballa* is a fish of fine flavor, and its relatively low repute in Peru is doubtless due to the fact that broiling is an almost unknown or unpracticed method of cooking fish. Prepared in any other way, the flesh of the *caballa* is too oily to vie with that of species more favored by Peruvians.

A local fishery for the *peje-espada,* or swordfish, which is a relative of the mackerels, is conducted from the port of Mollendo.

8. *Carangids.* A well represented family of which the *cojinova* (*Neptomenus crassus*), the *jurel* or scad (*Trachurus*), and the far-

FISH-EATING BIRDS ON SANTA ROSA ISLAND
These cormorants live chiefly upon anchovies, and the astounding abundance of the birds is an index of the remarkable fisheries resources of the Humboldt Current.

famed pámpano (*Trachinotus paloma*) are the most important Peruvian members.

9. *Sea Basses.* A family of many species, of which a number, such as the *cherlo* (*Acanthistius*), the *ojo de uva* (*Hemilutjanus*), the *cabrilla* (*Paralabrax*), and the several species of fishes known as *cabinsas* are familiar even though not highly regarded food fishes.

10. *Croakers and Drums.* Another well-represented group, with two or more species related to our North American squeteague or weakfish, together with two of the finest fishes of Peru, the *corvina* (*Sciæna gilberti*) and the robalo (*Sciæna starksi*). Both of the latter attain large size, sometimes weighing forty pounds, and both fetch a high price in the markets. These fishes always congregate at the outlets of the Peruvian rivers in times of flood, for the purpose of feeding upon small crustaceans which find their way from the fresh water into the sea.

11. *Flounders.* Flounders and their relatives are common and of good quality.

12. *Blennies.* The several kinds are plentiful, occurring everywhere about the islands and along rocky shores. Perhaps because of their abundance and grotesque appearance, and the fact that they are often a nuisance to fishermen, the blennies figure more or

A SCALLOP-DREDGING CHALUPA
With modified lug-rig. Callao: Fronton Island in the background.

less in folk-lore of the Peruvian coast. Thus two or three species are known as *borracho*, which means drunk. Fishermen at several places told me that eating the *borrachos* would produce intoxication or stupefaction. At the Chincha Islands I heard one species of *borracho* called also *sueño* (dream), the implication of which is no doubt similar.

13. *Cusk Eels.* The family of the *congrio* (*Genypterus*), an abundant and highly prized food fish, especially in the southerly parts of the coast. The *congrio* is sometimes known as the *bacalao del pais*, or "native cod," for it furnishes a desiccated food of first rank. The principal *congrio* fishery is in the vicinity of Mollendo, where the fishes are taken on trawl lines. Their reputation, however, extends to all parts of Peru.

At North Chincha Island I saw many *congrios* caught. The lines were set on dark nights, the legend that these fish would not take hooks in the moonlight evidently being fully credited. Excellent catches were made and I was able to observe the native method of preparing the famous *charqui* or *charquecito*. The fresh fish were split down the back, and, after cleaning, were soaked in the cool sea water for twenty-four hours or longer, until the blood had diffused out. Finally they were hung in the air, without salting, until the white flesh had thoroughly dried.

Earlier Attempts to Introduce Improved Methods

The opportunity for initiating more efficient and extensive

CHARACTERISTIC ROCK FISH FROM THE BALLESTAS ISLANDS
Left to right: 1, "mero" (*Oplegnathus insignis*); 2, "pintadilla" (*Cheilodactylus variegatus*); 3, "mulata" (*Pimelometopon darwinii*).

fisheries operations in Peru has occurred to many persons and has, indeed, been tried, although thus far without success. More than a century ago Joseph Skinner wrote:

"The fishery is a branch of industry exclusively belonging to the Indians situated on the coast; but they are destitute of skill, and, being at the same time unprovided with proper boats and fit instruments, keep constantly within sight of the coast, venturing but a very small distance to sea. Hence arise the scarcity and dearness of fish, so often experienced at Lima, and in all the places along the coast. A few years ago several boats of a particular construction were built for the purpose of fishing throughout the whole extent of these seas; but this scheme was shortly afterwards abandoned.[3]"

Not many years ago, a trawling venture was undertaken, the Scotch steamer "Alcatraz," which subsequently passed into the hands of the National Guano Administration, being employed with modern equipment for some months. The bottom proved rocky in most places, and hence not satisfactory for this type of fishing, but fish were, nevertheless, taken in abundance. The problem of a sufficient market, however, ultimately led to failure, for, when the sea-

[3] "The Present State of Peru," London, 1805, p. 8.

ports had been glutted with fish, means were lacking for transporting the catch to centers where it would have been in demand.

CONCLUSION

Beyond doubt organized fishing in Peru will eventually be conducted with success. The resources are great and varied; the bays offer inviting sites for stations; native fuel oil is obtainable in quantity; adaptable labor is already on the ground; the climatic conditions of the coastal ocean are almost without parallel; the government is eager to see the country's natural resources developed. A rich potential market exists along both coasts of South America and in the interior, besides which it is likely that many prepared products might profitably be exported to the Orient and even to the northern hemisphere.

INVERTEBRATE ANIMALS AND CIVILIZATION

By Professor GEORGE T. HARGITT
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IT is probable that man had his origin in a single locality and from there migrated to different regions of the earth, moving about "like the other migrating faunas, unconsciously, everywhere following the line of least resistance, advancing or receding, and acting generally on blind impulse rather than of any set purpose. . . . and further that these migrations took place prior to the development of all cultural appliances beyond the ability to wield a broken branch or a sapling, or else chip or flake primitive stone implements."[1] Thus man assumed his present erect posture and certain structural features long before he developed those religious, moral and intellectual faculties which we call human characters. Probably he was more or less social from the beginning.

From the common center of origin early man migrated to all parts of the earth's surface, and has given rise to the various races and tribes we now know, as well as to others which have become extinct. The facts also seem to force the conclusion that out of the original brute-like and instinctive life and activities have developed the variety of customs, activities and cultures found to-day in different races, including our complexly organized industrial life and the highly developed intellectual society of modern times. The migrations and the changes in habits as well have been influenced by or conditioned upon the many physical factors of the environment, such as climate, geographical location, geological and physiographic conditions. Likewise, the biological factors of the environment have influenced or determined the rate and kind of progress; the importance of plants and of the higher animals, especially mammals, for food, clothing and shelter are well known.

The lower animals have also contributed to the advancement and civilization of man, and to a much greater degree than most of us suppose. At the present time the chief competitors of man are the insects, and we must wage war with vigorous and unceasing

[1] Keane, A. H.: "Man Past and Present," Cambridge Univ. Press, 1900, p. 8.

activity to grow our food, protect our forests, our animals and ourselves from their attacks.

The following account will outline some of the relations of the invertebrate animals to man and the ways in which they may have assisted in the progress of his civilization. No attempt will be made to secure an exhaustive discussion, but only to suggest in a general way some of the many relations which might be considered.

Land Masses

The land areas of the earth's surface are due mainly to geological activities, the formation of beds of sedimentary rocks and their elevation above the water level. But considerable areas are due, directly or indirectly, to the lower animals. Of these animals the corals are the best known, and the great number of coral islands scattered through the Pacific Ocean have furnished places of habitation for many peoples. These tiny animals, living in great colonies and building great masses of lime as their skeleton, can not grow above water, but the fragments are broken loose, fill in the spaces between the branching corals, and other fragments are ground into sand which the waves pile above the water level. Later this sand may be consolidated into rock. In this way the Bermuda and Bahama Islands have been formed. The southern one hundred miles, or more, of Florida is built of limestone formed chiefly from coral sand and Yucatan and many islands of the West Indies are partly formed in the same way. Growing with the corals are great numbers of crustacea, clams and snails, starfish and sea-urchins and tube-forming worms; the calcareous shells of all these are ground up and help to form the sand which is consolidated into limestone.

Clams and snails have lived in great abundance, as they are now living, and in past ages have left masses of shells in enormous beds. These have been fragmented, sometimes ground into sand, and later consolidated into such rocks as the shell limestone or coquina of St. Augustine, Florida. In all parts of the world similar shell limestone is present, often in great abundance.

The lowest of the animals, the Protozoa whose microscopic body is composed of a single cell, contribute their remains to the formation of new deposits. Some of the Protozoa are encased in shells of lime for protection, and at death these shells drop to the ocean floor and form thick masses of soft ooze. Investigators of the sea floor have found all over the world masses of ooze which are composed almost entirely of these shells. This foraminiferan ooze is the most widespread of modern calcareous formations, over fifty millions of square miles of sea bottom being covered mainly by

the shells of foraminiferan Protozoa. When consolidated the accumulations form chalk. Beds of chalk extend from Ireland across Europe to the Caucasus Mountains, and from Sweden to France, the beds being a thousand feet thick in places. Such chalk beds were formed from foraminiferan ooze in past ages.

The lower animals have therefore contributed effectively and considerably to the formation of the land upon which man could live.

Soil

Soil is composed of disintegrated rock with organic substances intermingled. Invertebrate animals have contributed to the formation of the soil to the same extent that they aided in the production of the rock. However, it is in the preparation of the soil for plant growth that the invertebrates play a very large part.

In his book upon "Vegetable Mould and Earthworms" Charles Darwin gives a detailed account of the action of worms upon the soil. The earthworms pass earth through their bodies, grinding it in the gizzard into very fine particles and digesting out some of the organic matter which may be present. The earth itself passes out of the body again and is deposited at the surface of the burrows as castings. In this way deep-lying soil is brought to the surface, the earth is reduced to a very fine condition and mixed with organic matter. The burrows of the worms permit aeration of the soil, allow drainage and make pathways for the growth of roots. In many parts of England Darwin estimated that ten tons of earth for each acre of land is passed through the bodies of earthworms and brought to the surface each year. If this finely divided soil were spread out in a uniform layer over the land it would amount to a thickness, in some cases, of an inch to an inch and a half in ten years.

Darwin sums up the results of his observations and experiments as follows: "Worms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds. They periodically expose the mould to the air and sift it so that no stones larger than the particles which they can swallow are left in it. They mingle the whole intimately together, like a gardener who prepares fine soil for his choicest plants. In this state it is well fitted to retain moisture and to absorb all soluble substances, as well as for the process of nitrification. The bones of dead animals, the harder parts of insects, the shells of land molluscs, leaves, twigs, etc., are before long all buried beneath the accumulated castings of worms, and are thus brought in a more or less decayed state within reach of the roots of plants. Worms likewise drag an infinite number of dead leaves and other parts of

plants into their burrows, partly for the sake of plugging them up and partly as food.

"It may be doubted whether there are many other animals which have played so important a part in the history of the world as have these lowly organized creatures."[2]

Others have stated that the work of the earthworms is of greater significance and of more importance to man than perhaps all of the geological and physiographic factors combined.

Food

Primitive man was a plant-eater, subsisting upon roots, tubers and especially upon fruits. This has been determined from the character of the teeth in the jaws of primitive man. Gregory shows that man has passed through three stages in regard to character of teeth and food habits: (1) a chiefly frugivorous stage, (2) a predatory and omnivorous stage, (3) a stage in which food was softened by cooking. He outlines a possible explanation for the change from vegetable to animal food as follows: "At a time when tough-rined tubers and fruits were still the main element of the diet the nascent Hominidæ may have sought out the lairs and nesting places of many animals for the purpose of stealing the young and thus they may have learned to fight with and kill the enraged parents. They had also learned to fight in protecting their own nesting places and young."[3] To account further for the assumption of the predatory habit Gregory suggests that primitive man may have learned to use a stone to mash tough plants or to break bones; later he learned to throw stones, to use sharp stones as knives, to swing a piece of wood and so gradually came to the use of weapons and implements. After he learned to use weapons he became primarily a hunter and ceased to depend chiefly upon vegetable food.

These suggestions imply that man secured his animal food by hunting the larger forms, especially birds and mammals, and no doubt these were the chief dependence when they could be obtained. But we have evidence that great use was made of invertebrate animals as well. This may have been only at certain seasons or by certain tribes, but it was a widespread habit as is shown by the great refuse heaps of shells (kitchen-middens) found all over the world, in North and South America, Europe, Australia, New Zealand, Japan and other regions. In places such refuse heaps are fifty to seventy feet wide, twenty feet thick, and extend

[2] Darwin, Charles: "Vegetable Mould and Earthworms," D. Appleton & Co., 1900, pp. 312, 316.

[3] Gregory, Wm. K.: "Studies on the Evolution of the Primates," *Bull. Amer. Museum Nat. Hist.*, Vol. 35, p. 342.

for a thousand feet or more; they must have taken centuries to form. Lord Avebury[4] states that such shell heaps mean that communities of men lived there subsisting on molluscs and depositing the refuse shells in a heap. The evidence shows that these dwellers were permanent settlers and not merely summer visitors. In describing such kitchen-middens in Denmark Avebury mentions the chief mollusc shells as the oyster (*Ostrea edulis*), mussel (*Mytilus edulis*), cockle (*Cardium edule*) and periwinkle (*Littorina littorea*); but whelks (*Nassa* and *Buccinum*), clams (*Venus*), land snails (*Helix*) and other shells were present with a few remains of crabs and bones of fish, ducks, deer and wild boar. In every part of the world, along the seacoast, man lived almost entirely upon molluscs; the remains of other animals are so few as to show they were occasional and not staple articles of diet.

The dependence upon shell-fish for food and the formation of kitchen-middens is not limited to prehistoric man. Darwin[5] found that the inhabitants of Tierra del Fuego lived almost solely on shell-fish, varying this diet only with a few berries and fungi, an occasional putrid carcass of a whale or seal which drifted ashore, and a few fish captured on lines without hooks. These people constantly changed their place of residence but returned again and again to the same localities and kept adding to the shell heaps. When storms prevented the gathering of shell-fish the people went hungry, and they often suffered severely from famine. Darwin also found that on Chiloe and other islands of southern South America the Indians lived chiefly upon shell-fish and potatoes, though fish were sometimes caught, and rarely they kept a few pigs, sheep and fowls.

Subsistence wholly on shell-fish is no longer common, but the use of molluscs as a part of the diet is almost universal. Highly civilized races, and savage tribes as well, include a greater or less number of such forms in their food. In this country probably fewer kinds of molluscs are eaten than in any other civilized country, only the oyster and some of the clams suiting our tastes. May it not be possible that the experimentation of primitive man in the use of various shell-fish in different parts of the world accounts in part for the different tastes of living man?

The following molluscs are used as food to-day in various parts of the world: Bivalves—mussel (*Mytilus*), oyster (*Ostrea*), scallop (*Pecten*), fresh water clams (*Anodonta*; *Aetheria*), *Cardita*,

[4] Lord Avebury: "Origin of Civilization and the Primitive Condition of Man," Longmans, 6 ed., 1900.

[5] Darwin, Charles: "Journal of the Voyage of the Beagle," Appleton, 1905.

Pompano (*Donax*), surf or hen clam (*Mactra, Tresus, Lutraria*), quahog (*Venus*), great blue clam (*Schizothærus*), blunt nose clam (*Macoma*), *Tivela, Tapes,* cockle (*Cardium*), giant clam (*Tridacna*), bear's paw (*Hippopus*), *Panopœa,* soft clam (*Mya*), razor clam (*Solen, Siliqua*), rock-boring clams (*Lithodomus, Saxidomus, Pholas, Pholadidea*); Univalves or snails—limpet (*Patella*), Abalone or ear shell (*Haliotis*), shield shell (*Scutus*), top shell (*Trochus*), turban (*Turbo*), sea snails, bleeding tooth (*Nerita, Neritina, Navicella*), *Murex, Purpura,* hare's ear (*Concholepas*), whelks (*Buccinum, Eburna, Neptunea, Nassa*), *Voluta,* auger shell (*Tenebra*), moon shell (*Natica*), periwinkle (*Littorina*), pond snail (*Paludina*), apple snail (*Ampullaria*), conch (*Strombus*), pelican's foot (*Aporrhaïs*), *Triton,* sea hare (*Aplysia*), roman snail (*Helix*) and chitons; among the cephalopods, the devil fish (*Octopus*), squid (*Loligo*) and cuttle fish (*Sepia*).

No other group of invertebrates has formed so staple an article of diet from the earliest times as have the molluscs. Primitive man did make some use of crustacea, since the skeletons of crabs have been found in kitchen-middens, but these were clearly not much sought for, possibly because of greater difficulty in capture. In modern times many crustacea appear on our bill of fare: lobsters (*Homarus, Palinurus, Scyllarus*), shrimps and prawns (*Crangon, Palæmon, Peneus, Pandalus*), crayfish (*Astacus, Cambarus, Panulirus, Iasus*), crabs (*Cancer, Callinectes, Ovalipes, Carcinus, Birgus*), mantis shrimp (*Squilla*) and others.

Insects are used as food mostly by savage tribes, though Arabs and Syrians gather locusts, pull off the wings and legs and eat the roasted bodies, or they dry the locusts in the sun and preserve them for future consumption. The American Indian gathered the nymphs of the 17-year cicada as they emerged from the ground, roasted them in a hot oven, or pounded them to make a sort of batter which was cooked and eaten; the same practice is followed by Indian tribes in central New York to-day. The Australian natives are recorded as eating ants, caterpillars, moths, beetles and grubs of all kinds either raw or cooked, and night-flying moths are pounded into a paste and cooked. African natives use the large fleshy grubs like those of our May beetles, and also other insects, pounding the bodies of May flies into paste. Hans Coudenhove[6] has described the food habits of living African natives as follows: "The natives catch the winged termites or white ants, devour them alive, devour them dead, raw or fried or roasted, or dried in the sun, or pounded to a paste. They pack them in bags like beans, alive or dead, and sell them on the market." "Several kinds of

[6] Coudenhove, Hans: *Atlantic Monthly*, October, 1921; March, 1922.

caterpillars, both smooth and hairy, are collected in baskets and eaten as a relish; locusts and white ants replace in the native cuisine our oysters and turtles; and some people are particularly fond of a large, strong-smelling tree-bug." "Up to fifteen years ago in the so-called Kaffir eating houses on the Rand, native mining boys used to buy, by preference, meat full of grubs. They said it was richer."

The segmented or annelid worms are not commonly used as food by man, but some of the nereids are eagerly sought for by natives of Tonga, Samoa and the Fiji Islands. At the breeding season these worms swarm to the surface of the sea in countless numbers to spawn. The Palolo worm (*Palolo viridis*) appears on two days in October and on two in November of each year at certain phases of the moon. Saville-Kent[7] states that the natives assemble the night before the appearance of the worm, which by them "is regarded as one of the daintiest luxuries their territories produce." When the swarming begins, about dawn, the worms are scooped into canoes with hands, nets and other receptacles. In the feast which follows the worms are eaten raw or wrapped in plantain leaves and baked. Quantities are sent inland to other tribes. A similar worm with similar habits is eaten by the natives of the New Hebrides.

Echinoderms, though apparently without attraction to most people, are eaten by some. In France and Italy large numbers of the common sea-urchins are used as food, and the natives of the West Indies eat the large urchin *Tripneustes*. The trepang or Bêche-de-mer of the Chinese is made from the dried bodies of the sea-cucumbers, *Stichopus* and *Holothuria*. These are gathered in Australia and elsewhere from the coral reefs, boiled in water, the body cut open and eviscerated and dried in the sun; they may also be smoked after drying. When thoroughly dry they are packed and shipped. Saville-Kent records several hundred tons of dried trepang as shipped from Queensland, Australia, in a single year.

Ornamentation

That some sense of beauty is inherent in man is indicated by the care and ornamentation he gives to his person and his effects. Such a sense seems to have been present from the beginning. The expression of this sense in primitive man and in living savages seems very strange and perverted to civilized people. But from the savage viewpoint our own sense of beauty is just as strange and unaccountable.

Probably in primitive man, and certainly in savages, orna-

[7] Saville-Kent, W.: "The Great Barrier Reef of Australia," London, 1893.

mentation commonly takes the direction of smearing or painting the body with colored earth or pigments, and tattooing or mutilating the body. But in addition all sorts of objects are used for adornment in the form of necklaces and the like. The shells of molluscs are perhaps among the oldest and most common objects used for ornamentation. Either in the natural state, or modified by grinding into beads and fragments, shells were constructed into necklaces, armlets, bracelets, anklets, nose, ear and lip ornaments. Shields, war and hunting implements, drums, canoes and other appliances were decorated with shells. Large and uncommon or striking shells were used as symbols of rank and influence in the tribe. No doubt almost all of the common shells have been used in this way, especially if they were attractive in form or color.

With the progress of civilization comparatively little change has occurred in the matter of adornment. We still use necklaces, bracelets, ear and finger rings. Instead of lip and nose ornaments and tattooing, we ornament our clothing, and civilized people still powder and paint the exposed portions of their bodies. Among the invertebrates used by living civilized people the molluscs furnish the greatest variety. Articles of jewelry, brooches, rings, studs and buttons are made from *Haliotis, Turbinella, Cypræa, Turbo, Trochus, Meleagrina.* Mother-of-pearl is obtained from *Haliotis, Meleagrina* and others. Pearls are obtained from a variety of molluscs, chiefly from the pearl oyster (*Meleagrina margaritifera*), but also from fresh water clams of the family *Unionidæ*, and from marine clams, as *Ostrea, Venus* and *Tridacna.* Occasionally green pearls are found in *Haliotis*, pink pearls in *Strombus*, black pearls in *Pinna.* Cameos are cut from several of the marine snails as the queen conch (*Strombus gigas*), bull's mouth helmet (*Cassis rufa*), black helmet (*Cassis cameo*), and the orange helmet (*Cassis cornuta*). The pearl buttons we use come mostly from the shells of fresh water clams of the Mississippi valley, some forty-one species being of commercial value.

Aside from the molluscs only the precious red coral (*Corallium rubrum*) among the invertebrates furnishes us with material for jewelry.

Ornamentation is accomplished by clothing, aside from the adornments added, and other invertebrates have been of service in furnishing dyes to man. One of the most famous of the dyes was the Tyrian or "Phoenecian purple" of Mediterranean peoples. This was obtained from marine snails of different sorts, chiefly *Murex* and *Purpura.* Heaps of shells of *Murex trunculus* are still found along the Tyrian coast and *Murex brandaris* on the Greek and Italian shores; along with these are different species of

Purpura. The molluscs were pounded in hollow rocks, the fluid so obtained separated by squeezing, water and soda added and the liquor boiled. Wool dyed with this is stated to have been worth $200 a pound, and only royalty could afford its use.

The cochineal insect (*Coccus cacti*) lives upon cactus plants of the prickly pear group in Mexico, but has been introduced and cultivated in South America, Spain and Algiers. The bodies of the insect were brushed into bags and killed by immersion in hot water or by exposure to steam or sun. From these dried bodies the red dye carmine was obtained, which was especially valuable for staining wool a brilliant red. A similar red dye obtained from the lac insect has for centuries been used in India. Dyes obtained from the cochineal and lac insects have been almost replaced by the synthetic chemical dyes.

MONEY

While the method of barter was the first means of acquiring materials or appliances, it is certain that a definite medium of exchange was devised very early in the progress of civilization. Shells were used as money by ancient man, and even to-day some savage tribes pay their taxes and acquire merchandise and property with shell money. The eastern American Indians obtained their wampum by making beads from the shells of marine molluscs. White beads were made from the whelks (*Busycon carica, B. canaliculatum, Baccinum undatum*) or quahog (*Venus mercenaria*). The more valuable purple beads came from the purple portions of the shell of the quahog. In California and on the west coast the Indians strung the shells of the elephant's tooth shell (*Dentalium*) and used these strings as money. A string of twenty-five shells might be worth a canoe or a comely woman. It is said that in the early days this money was so abundant that "every Indian possessed an average of at least $100 worth of shell money. This would represent the value of about two women, or two grizzly bear skins, or twenty-five cinnamon bear skins, or about three average ponies."[8] In addition to the use of Dentalium Stearns[9] states that the west coast Indians also made beads or disks from *Olivella, Haliotis, Fissurella, Saxidomus* and *Pachydesma.*

In the Pacific islands, India and Africa the money cowry (*Cypræa moneta*) was the principal shell used as money, though *Cypræa annulus, Littorina, Nerita* and *Ovula* shells were also used. The cowry is probably still used in parts of Africa to a limited extent, where formerly it was the sole medium of exchange and

[8] Rogers, Julia E.: "The Shell Book," Doubleday, Page & Co., 1908, p. 300.

[9] Stearns, R. E. C.: "Aboriginal Shell Money," *Amer. Nat.*, 1877, Vol. 11.

used in the paying of taxes, the purchase of wives (which might cost from 25,000 to 100,000 cowries, depending upon age, beauty and the like) and all other purposes which money would serve. An old story, attributed to Reeve, is that of a house built in India and paid for entirely in cowries, sixteen million being required.

Industries

Mention has already been made of the formation of limestones from the remains of invertebrate animals. There are many limestones which have an organic origin, such as the shells of foraminifers, fragments of coral, of crinoids, of mollusc shells of various sorts. Most of these are valuable for building stones. The nummulitic limestones which were largely used in the building of the pyramids of Egypt are consolidated foraminiferan shells. In Bermuda and elsewhere the coral limestones furnish most of the stones for building. Thomson[10] refers to the excellence of this coral limestone in Bermuda. "The stone is cut out of the quarry in rectangular blocks by means of a peculiarly constructed saw, and the blocks, at first soft, harden rapidly, like some of the white limestones of the Paris basin, on being exposed to the air." Coquina limestone, composed of cemented fragments of mollusc shells, has also been used for building purposes in Florida.

The only road metal available in certain regions of the world consists of the shells of recent molluscs. These are often found in enormous beds and are either broken up and applied to the road or used as obtained and ground up by the traffic. Without such material to draw from it would be impossible in certain parts of Florida, for example, to construct hard roads without great expense from imported material. In other places the shell and coral limestone is crushed for the building of roads.

Chalk is too soft and friable to furnish building stones, but it serves a no less valuable purpose as an ingredient of paints, cements and putty. Lime may be obtained from chalk and also from shells and shell limestone.

The lac insect (*Coccus lacca*), which is allied to the cochineal and other scale insects, furnishes us with our only source of shellac. These insects, which pierce the bark of twigs to secure the sap as food, secrete a resinous substance over the entire body as a protection. This hardens into scale like plates, and since the insects are usually present in great numbers, the twigs and branches of the shrubs may be entirely enclosed within this resinous substance. The twigs covered with the encrusted insects are gathered and

[10] Thomson, C. Wyville: "The Atlantic" (Narrative of the *Challenger* Expedition), Harpers, 1878.

this furnishes the "stick lac" of commerce; if the resin is crushed into fragments and washed in hot water we have "seed lac," while the "shell-lac" is obtained by melting the resin, straining it through canvas and drying in thin layers. We are entirely dependent upon this insect for our shellac, which is the principal ingredient in sealing wax and other cements; its chief use, however, is in the making of fine varnishes and lacquers.

Dynamite, so necessary in construction work, is composed of nitroglycerin mixed with an inert absorbent material. One of the most satisfactory absorbents for this purpose is infusorial or diatomaceous earth. The former consists of the silicious shells of unicellular animals, while the shells present in diatomaceous earth are those of unicellular plants. Other materials besides this infusorial earth may be used as absorbents of the nitroglycerin, but this seems to be one of the most satisfactory.

Arts and Sciences

Just as the invertebrates have contributed to various industries, they have in some measure aided the arts and sciences. The ink used by man to express his thoughts was formerly obtained chiefly from gall nuts, those from oak trees being more abundant, though such galls occur on many plants. The galls were powdered and the extract leached out and mixed with an iron salt. Such ink became blacker after writing, due to oxidation, and thus made a valuable ink since it entered the fibers of the paper and was difficult to remove or erase. The galls are plant growths, but such growth is stimulated by small insects, usually gall wasps. The insects lay their eggs in the leaves or stems of the plants, and the hatching and growth of the larva stimulates the plant to the growth of this gall, which serves as a sort of nursery for the developing animal. Gall nuts formed the basis for the tattooing colors of some savages.

The sepia pigment and the india ink of artists was at one time obtained only from cephalopod molluscs, such as the cuttlefish, octopus and others. The scientific name of the cuttlefish is *Sepia*. These molluscs contain an ink gland which secretes a fluid used for protection by the animals. In China the animals were thrown into vats and the ink collected as it exuded from the dead bodies. In Mediterranean countries the ink sac was removed, carefully dried and powdered, the powder dissolved in caustic alkali and then precipitated with acid. After washing in water and drying, the powdered sepia was ready to be made up in any form required.

If one were to suggest that our knowledge of the heavenly bodies and progress in astronomy or that careful surveys and measurements of terrestrial distances were dependent upon the lower animals, he might be considered as not quite normal. Care-

ful and accurate measurements are essential in such work, and these demand micrometers of various sorts. The cross hairs in micrometers for telescopes, microscopes, theodolites and other similar instruments are often composed of strands of spider web, which, because more delicate, may serve better than metal wires. Hence, in a measure the advance of these sciences may be dependent upon the spider.

MEDICINE

Records are wanting as to what, if any, use the invertebrates were to primitive man in medicine. But civilized races in different parts of the world have had weird ideas as to the effectiveness of invertebrates in a great variety of human ills. Many of these practices are doubtless still in use by ignorant people as home remedies, but only a few centuries ago they were the standard and approved methods of the leading medical men.

Snails, especially the garden slugs, seem to have been favorites for all kinds of treatment, as we may judge from the many records of their use. For headache a plaster was made from the bodies of these slimy animals; for tuberculosis they were boiled in milk and the mixture drunk, or small living slugs without any previous treatment were placed on the tongue and swallowed without crushing. Pliny suggests eating an uneven number of them to cure cough and stomach ache. One of the royal physicians of England, as reported by Hulme,[11] recommends for deafness: "Take a gray snail, prick him, and put ye water which comes from him into ye ear and stop it with black wool, and it will cure." Slugs have been used for corns, pleurisy, malaria, burns, asthma and skin diseases.

Until about fifty years ago the leech was much esteemed as a sovereign remedy for everything; it was equally effective for apoplexy and for fainting, for fever and for chills; the first thing the physician did was to clap leeches on the patient and thus bleed him. Records show that seven million leeches were used in London hospitals in 1863 and more millions were used in other cities and countries. Leech farms were conducted for the purpose of raising leeches to supply this need, and drug stores kept a constant supply on hand. In older days leeches had other values and Pliny gives a recipe for a hair dye obtained from them: "Leeches left to putrefy for forty days in red wine stain the hair black. Others, again, recommend one sextarius of leeches to be left to putrefy the same number of days in a leaden vessel, with two sextarii of vinegar, the hair to be well rubbed with the mix-

[11] Hulme, F. E., "Natural History Lore and Legend," London, 1895.

ture in the sun. According to Sernatius this preparation is, naturally, so penetrating that if females, when they apply it, do not take the precaution of keeping some oil in the mouth, the teeth, even, will be become blackened thereby.'"[12]

Ashton records the ancient use of river crabs as remedies for poisoning. These are used fresh, beaten up and drunk in water, or they are burned and the ashes mixed with asses' milk as an antidote for scorpion poisoning. The ashes in red wine is good for rabies.

Insects had their place in ancient pharmacopeias, and Williams[13] quotes an old Egyptian formula: "Against all kinds of witchcraft a great scarabæus beetle; cut off his head and wings; boil him; put him in oil and lay him out; then cook his head and wings, put them in snake fat, boil and let the patient drink the mixture." Dental pains were cured by placing a small caterpillar in the cavity of the tooth and closing it up with wax. The use of cantharidin continues to the present day as a blistering agent, and this is obtained from the dried bodies of certain beetles called blister beetles.

The spider was chiefly useful for chills and contagion. Hulme[11] records the use of a living spider shut up in a box and carried around to draw from the air the contagion which would otherwise infect the person. From a diary of 1651 this entry is quoted: "I took early in the morning a good dose of elixir, and hung three spiders about my neck, ague away, Deo gratias." In southern England the spider was a favorite remedy for jaundice. Pills were made from spider web, or a living spider was rolled in butter to make a pill, which was taken.

Such records show that the invertebrates were believed to have great merit as remedies for certain diseases and ailments. In our modern pharmacopeia we have discarded all such, and most other of ancient animal drugs, but we have retained many of the plants used by the ancients.

Religion

The invertebrate animals have not had the same appeal to man for religious rites as have the vertebrate animals and inanimate objects. But there are a number of these lower animals which have been considered sacred. To the Hindus the chank shell (*Turbinella pyrum*) is a very sacred object, and images of the god Vishnu carry this shell in one hand. The shell is an object of veneration to the people, who address their petitions to it at the

[12] Ashton, John: "Curious Creatures in Zoology."

[13] Williams, H. S.: "History of Science," Vol. 1, p. 48.

beginning of each prayer. Priests make sacred vessels of the shell, which may be carved and ornamented for this purpose.

The scarab beetle (*Scarabæus sacer*) was one of the many animals sacred to the Egyptians, and symbolized to them the sun and the earth. Avebury[4] refers to one of the beliefs of the Pacific islanders as follows: "The Bishop of Wellington informs us that spiders were special objects of reverence to Maoris; and, as the priests further told them that the souls of the faithful went to heaven in gossamer threads, they were very careful not to break any spider's web."

Modern Civilization and Insects

We suffer enormous money losses each year in this country from the attacks of insects upon our food and other crops, upon live stock, forests and in other ways. In other places one may find the statistics dealing with these great losses which exceed two billions each year. Apart from this actual damage insects may influence or actually condition certain of our activities. The spread of the cotton-boll-worm through the southern states seems destined to change entirely the agricultural policy and practice of these regions. The growing of cotton as the principal crop is being replaced by a diversity and rotation of other crops, with cotton only one of the products. In other words since we can not overcome nor successfully meet the attacks of this insect we must change our habits.

Perhaps the most striking examples of the influence of insects on modern civilization relate to the insects as carriers of disease. Celli in his book on malaria states that the greater activity and industry found in northern Italy, as compared with southern Italy, is due to the prevalence of malaria in the latter region. And he further suggests that the growth of cities and development of agriculture in parts of Italy has been determined by the prevalence of malaria. This determination is therefore due to the presence of the mosquito, for the malaria is spread only by this insect.

It was the mosquito which prevented the French from cutting a canal at Panama, and it was only when our own sanitarians conquered the mosquito that we were able to complete the work. In all tropical and sub-tropical climates the handicap which the white man has had to endure, and the reason for the lack of colonization, and therefore for the spread of his civilization to these regions, is the prevalence of fevers. And this involves the presence of mosquitoes and biting flies, for in all probability all the tropical fevers are spread by insects. Man can live in the tropics safely and healthfully if he can subdue the insects which carry disease; the evidence of this is clear and positive from the record of the United States in Cuba, Panama and the Philippines.

There is no group of animals, vertebrate or invertebrate, which has so much significance to man as the group of insects. They touch almost every activity and interest of civilized life. They attack our growing food, our stored food, our orchards and forests, our clothing and our dwellings. Our bodies and those of our domestic animals are annoyed or infected with disease germs through the activities of insects. They are our chief competitors in the struggle for existence, and our fight against them is getting more severe and costly every year. Howard[14] has stated it as a matter of doubt whether in the next few centuries man will be able to maintain himself against this group, or whether he will succumb and leave the earth to the insects as the dominant type of animal.

When we consider such a possible outlook we have a striking, not to say startling, impression of the relationships of man and the lower animals.

[14] Howard, L. O.: "The Contribution of Zoology to Human Welfare," *Science*, 1918, Vol. 47, p. 352.

FOOD CONTROL DURING FORTY-SIX CENTURIES[1]

By MARY G. LACY

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THE man, or class of men, who controls the supply of essential foods is in possession of the supreme power. The safeguarding of the food supply has therefore been the concern of governments since they have been in existence. They had to exercise this control in order to hold the supreme power, because all the people need food, and it is the only commodity of which this is true.

In connection with this control it would seem that every possible expedient and experiment had been tried. One of the most frequent methods of control used has been the limitation of prices by legal enactment. The results have been astonishingly uniform considering the variety of conditions and circumstances under which the experiments have taken place. They make an interesting record and one which contains food for thought, for the problem of the people's welfare has been much the same in all ages and it is not yet solved.

EGYPT: 2830 B. C.

As far back as the fifth dynasty in Egypt, which historians place at 2830 B. C. at the latest, there was inscribed on the tomb of the nomarch Henku: "I was lord and overseer of southern grain in this nome."

In the Book of Genesis[2] there are various references to the fact that Egypt was a granary where all the people were sure of finding a plenteous store of corn.

[1] No attempt has been made in this paper to cover the history of price-fixing since 1800. Government monopolies, such as the Brazilian valorization of coffee, the tobacco monopoly in France and that of sugar in Germany, as well as others which might be mentioned, have been fully reported by others. The history of price-fixing in the United States during the war of 1914-18 has also been written in the bulletins of the War Industries Board on the history of prices during the war. Litman gives a good account of Great Britain and the United States in his "Prices and Price Control in Great Britain and the United States during the War."

[2] Genesis xli: 1-10; xli: 54; xlii: 2.

The well-known story of Joseph shows how the control of the food supply by the government reduced a people to slavery. Joseph gathered and stored for Pharaoh in years of abundance one fifth of all the harvests. The improvident Egyptians lived well and laid by no stores. When famine came they and the people in the nearby countries went to Joseph and bought food from him until all their money was gone; then they gave him their cattle for food; after they had bartered away all their cattle they offered their land and themselves in exchange for subsistence. Having thus reduced them to slavery as the price of life, Joseph about 1700[3] B. C. gave them seed and put them on the land again. Flavius Josephus[4] tells the story as follows:

When famine came, the multitude, sorely oppressed, repaired in crowds to the stores and magazines of the king. The situation of the poorer and common sort was piteous beyond description; for having laid in but a very scanty store, and not being able to obtain a supply without ready money, when that was exhausted, they were reduced to the necessity of exchanging their cattle, slaves, lands, nay, their last little all, to procure grain from the king's granaries to protract a needy miserable life. When, by these means, they became totally destitute, they were abandoned to a desolate world, that the king might secure their bartered possessions. . . . But when at length the river overflowed, watered the earth, revived drooping nature, and produced a fertile aspect, Joseph made the tour of the kingdom, and summoning the respective landholders, restored to them such parts as they had sold to the king, on condition of their paying a fifth, as tribute to him by virtue of his prerogative and then enjoined them to the same diligence in their improvements, as if they were to derive the emoluments resulting from the whole. Transported at the returning prospect of plenty, and the restitution of their landed property, the people applied themselves to agriculture with unremitting assiduity; so that by this well-timed act of policy, Joseph established his own authority in Egypt, and increased the standing revenue of all its succeeding monarchs.

The great Egyptologist, Erman,[5] corroborates the testimony of Josephus by giving an account of the government control over grain and descriptions of the granaries which were surprisingly like our elevators—the grain being poured in at the top and taken out at the bottom by means of a sliding door. The outstanding

[3] Some scholars place the date at 2082 B.C. and still others at 1500 B.C. It was probably in the reign of Aphobis, at the end of the seventeenth dynasty, according to Dr. Henry Brugsch, in his history of Egypt under the pharaohs. Trans. by Philip Smith (London: John Murray, v. 1, pp. 300-306).

[4] Josephus, Flavius: "History of the Antiquities of the Jews." Ed. by George Henry Mayard. London: C. Cooke, 1789. Bk. 11, Chap. VI and VIII.

[5] Erman, Adolf: "Life in Ancient Egypt." Tr. by H. M. Tirard. London and N. Y.: Macmillan & Co., 1894. Pp. 107-108, 433-434.

Original sources: Lepsius, Richard, "Denkmäler aus Aegypten und Aethiopen," Berlin: 1849-59. Vol. 3, pp. 76, 77. Papyrus Abbott, published in the "Select Papyri in the Hieratic Character from the Collections of the British Museum." London: 1844-60.

result of the Egyptian control of the grain crop was a system of land tenure by which the land became the property of the monarch, and was rented from him by the agricultural class.

CHINA: 424-387 B. C.

In his study entitled "The Economic Principles of Confucius and His School," Dr. Chen[6] tells us that in China it was recognized from early times that

> . . . there are two sets of interests, those of producers and those of consumers. But nothing more markedly affects the interests of both sides at once than prices. Therefore, price is the great problem for society as a whole. According to the Confucian theory, the government should level prices by the adjustment of demand and supply, in order to guarantee the cost of the producer and satisfy the wants of the consumer.
>
> Its chief aim is to destroy all monopoly so that the independent or small producer can be protected on the one side, and the consumer on the other. It prevents the middle-man from making large profits, and gives the seller and buyer full gain. It is the task of the superior man to adjust demand and supply so as to keep prices on a level.

The means used by the Chinese government to this end are of the greatest interest, because of the economic principles involved and also because of their antiquity.

We are told that, "according to the official system of Chou (about 1122 B. C.) the superintendent of grain looked around the fields and determined the amount of grain to be collected or issued, in accordance with the condition of the crop; fulfilling the deficit of their demand and adjusting their supply."

> When Li K'o became the minister of Wei he said that if the price of grain were too high, it would hurt the consumers, and that if it were too low, it would hurt the farmers. If the consumers were hurt the people would emigrate, and if the farmers were hurt, the state would be poor. The bad results of a high price and a low price are the same. Therefore, a good statesman would keep the people from injury and give more encouragement to the farmers.

After describing the bad condition of the farmers he gives the following law for equalizing the price of grain:

> Those who want to equalize the price of grain must be careful to look at the crop. There are three grades of good crops: The first, the second and the lowest. In an ordinary year one hundred acres of land yield one hundred fifty bushels of grain.[7] In the first grade of good crop the amount is fourfold—that is, one hundred acres yield six hundred bushels. Throughout one year, a family of five persons needs two hundred bushels for their living, so

[6] Chen, Huan-Chang: "The Economic Principles of Confucius and His School." N. Y.: Longmans, Green and Co., 1911. (In Columbia Univ. Studies in History, Economics and Public Law, v. 44 and 45.)

[7] It is evident from the context that "grain" as used in these translations rice.

that they have a surplus of four hundred bushels. The government should buy three hundred bushels from them, leaving them a surplus of one hundred bushels. In the second grade of good crop, the amount of grain is threefold—that is, one hundred acres yield four hundred fifty bushels. The family would then have a surplus of three hundred bushels. The government should buy two hundred bushels, leaving them one hundred bushels. In the lowest grade of good crop, the amount is twofold—that is, three hundred bushels. The family would then have a surplus of one hundred bushels. The government should buy fifty bushels and leave them the other half. The purchase of the government is for the purpose of limiting the supply according to the amount demanded by the people, and it should be stopped when the price is normal. This policy will prevent the price of grain from falling below the normal and keep the farmers from injury.

There are also three grades of famine: the great famine, the middle famine and the small famine. During the small famine one hundred acres yield two thirds as much grain as in the ordinary year—that is, one hundred bushels. The government should then sell at the normal price what it has bought in the lowest grade of good crop. During the middle famine, the hundred acres yield one half as much grain as in an ordinary year, that is, seventy bushels. The government should now sell what it has bought in the second grade of good crop. During the great famine the amount of grain is only one fifth of what it is in an ordinary year—that is, thirty bushels. The government should sell what it has bought in the first grade of good crop. Therefore, even if famine, flood and drought should occur, the price of grain would not be high, and the people would not be obliged to emigrate. This would come about because the government takes the surplus of good crops to fill the insufficiency of bad years. In other words, the government controls the excess of supply in a good year in order to meet the demand in a bad year.

The policy of Li K'o is for the benefit of both society as a whole and the agricultural class . . . when his scheme was carried out in Wei, he not only made the people rich, but also made the state strong.

The principle of adjusting the supply and demand of grain is found also in the writing of Mencius, who lived 372-289 B. C. Dr. Chen quotes him as saying to King Hui of Laing:

When the grain is so abundant that the dogs and swine eat the food of man, you do not make any collection for storage. When there are people dying from famine on the roads, you do not issue the stores of your granaries for them. When people thus die, and you say, "It is not owing to me; it is owing to the year," in what does this differ from stabbing a man and killing him, and then saying, "It was not I; it was the weapon"?

The starving millions of China during 1921 might well have wished for so statesmanlike an advocate in the councils of their government as this fearless economist three hundred years before the Christian era. Dr. Chen proceeds to say:

The principle of equalizing the price of grain advocated by Li K'o and Mencius was adopted into the system of "constantly normal granary." During the reign of Han Hsuan Ti, when there were good crops for many years, the price of one bushel of grain was as low as five pennies. Then the farmers suffered greatly. In 498 (54 B.C.) Keng Shou-ch'ang proposed that the government should buy grain from places near the capital instead of

transporting it from the eastern provinces. According to the old custom of the Han dynasty, the government transported annually from the eastern provinces four million bushels of grain to supply the capital, which was in the province of Shensi in northwestern China. As this transportation was by means of the waterway, the number of laborers amounted to sixty thousand. By the plan of Ken Shou-ch'ang, which was approved and carried out by the emperor, the government saved more than half the expense of transportation, and the farmers got more profit. Then Ken Shou-ch'ang proposed that all the provinces along the boundary of the empire should establish granaries. When the price of grain was low, they should buy it at the normal price, higher than the market price, in order to profit the farmers.

Dr. Chen points out that the equalization of the price of grain is a very beneficial and practical scheme. It benefits the people without cost to the state. When the price is too low, though the government buys the grain at a price higher than the market rate, this does not mean a waste to the government. When the price is too high, though the government sells the grain at a price lower than the market rate, it does not mean a loss to the government. Even if it should be an expense to the government the social benefit is much greater than the public expense. On the contrary, as a matter of fact, the system has been more than once administered so as to make money for the government.

The few criticisms which have been made of it are shown by Dr. Chen ". . . to be the results not of the original law itself, but of the administration of man. The chief difficulty in administering it is that it is not easy for officials to undertake commercial functions along with political duties."

ATHENS: 404-337 B. C.

Xenophon tells us that in Athens a knowledge of the grain business was considered one of the qualities of a statesman. This was probably because Attica needed a considerable importation of grain, as the country did not produce a sufficient amount for its needs. It was brought to market in the Piræus from all quarters, from Pontus, Thrace, Syria, Egypt, Lybia and Sicily. A great quantity was imported, but not all for domestic use—some of it was to be sold in the Piræus to foreigners. It has been estimated by Boeckh that Attica needed annually 3,400,000 medimni[8] of grain, about half of which it could produce in a good season. This left, as the lowest of needed importations, 1,700,000 medimni or 1,133,-333 1/3 bushels. In an unpropitious season, when the domestic crop was scanty, this amount of importation was far from sufficient, so that one of the first objects of an Athenian statesman was to provide for an adequate supply of imported grain, and the

[8] A medimnus was equal to two thirds of a bushel or eight gallons.

regulations in regard to the grain trade were very important. Boeckh,[9] in his "Public economy of the Athenians," says:

The exportation of grain was absolutely prohibited. It was required by law that two thirds of the grain which came from a foreign country to the Attic emporium should be brought into the city: that is, only a third of the grain brought into the emporium in the Piræus could be exported from it to other lands. The execution of this law was committed to the overseers of the emporium.

In order to prevent as much as possible the accumulation of grain and the withholding it from sale, forestalling it was confined within very narrow bounds. It was not allowed to buy at one time more than fifty backloads (about 75 bushels). The transgression of this law was punished with death. The grain dealers were also not permitted to sell the medimnus of grain at a higher price than one obulus (three cents) more than they had paid for it. These dealers, who were commonly aliens under the protection of the state, enhanced the price, notwithstanding, by overbidding others in the purchase of grain in time of scarcity, and they often sold it the same day on which they purchased it at an advance of a drachma (17.1 cents) on the medimnus. Lysias can not relate particulars enough respecting the profligacy of these extortioners. They were hated full as much as the same class in modern times. . . "Were they not menaced with the punishment of death," said he, "they would hardly be endurable." While the agoranomi (market masters) had the superintendence of the sale of all other commodities, the state, in order to prevent the extortion of the grain dealers, appointed a particular body of officers called the sitophylaces (grain inspectors) to have the oversight of this single business. . . . They kept accounts of the grain imported, and besides the oversight of grain, they had also the inspection of meal and bread, that they might be sold according to legal weight and price.

The oration against the grain dealers delivered by Lysias[10] about 387 B. C. is of the greatest interest because of the light it throws on the speculative practices of the grain dealers in Athens, the great wheat market of the eastern Mediterranean and the attempts of a harassed government to control them. From it we glean that, in spite of the rigorous laws which were in force regulating the traffic in grain, "corners" were not uncommon. He wrote:

For when you happen to be most in want of grain, they grab it and are unwilling to sell, and you may be well satisfied to buy from them at any price whatever and take your leave of them so that sometimes when there is peace we are reduced to a state of siege by them.

We learn also that the "market masters," who as we have said before had the superintendence of the sale of all other commodities, were not considered sufficient to handle the grain trade also, but

[9] Boeckh, August: "The Public Economy of the Athenians." Tr. by Anthony Lamb. Boston: Little, Brown & Co., 1857. Book 1, Chap. 15.

[10] Lysias: "Against the Grain Dealers." (In Eight Orations of Lysias. Ed. by Morris H. Morgan. Boston: Ginn & Co., 1895. Pp. 89-103). For translation see Botsford, G. W., and E. G. Sihler, "Hellenic Civilization." N. Y.: Columbia Univ. Press, 1915, pp. 426-430.

that "grain inspectors" were appointed for this duty alone and it required fifteen of them to take care of the trade in the city and port of Athens.[11] Being a grain inspector at that time was no sinecure, for Lysias says:

> Ofttimes you imposed upon them, citizens though they were, the most severe penalties, because they were unable to master the scoundrelism of these dealers. What then should the malefactors themselves suffer at your hands, when you even put to death those who are not able to maintain a watch over them.

We learn further that there were "combinations in restraint of trade" at this early date, nearly four centuries before the Christian era, for Lysias says:

> For if you shall find them guiltless when they themselves admit that they made a combination against the importers, you will seem to plot against the skippers who came here.

We also learn that the results of even the most severe punishments, unaccompanied by any constructive substitute for the forbidden practices, were highly unsatisfactory, for Lysias says:

> But it is necessary, gentlemen of the jury, to chastise them not only for the sake of the past, but also as an example for the future; for as things now are they will be hardly endurable. And consider that in consequence of this vocation very many already have stood trial for their life; and so great are the emoluments which they derive from it that they prefer to risk their life every day rather than to cease to draw from you unjust profits. And indeed, not even if they entreat you and supplicate, would you justly pity them, but much more rather the citizens who perished on account of their wickedness, and the importers against whom they made a combination. . . . If then you shall condemn them, you shall act justly and you will buy grain cheaper; otherwise dearer.

Rome: 301-361 A. D.

Rome, not having had the foresight to prevent it, found herself confronted at the close of the third century of the Christian era with a condition of high prices which was very menacing. Diocletian, with characteristic vigor, proceeded to correct this condition by laws and issued his famous Edict in 301 A. D. Abbott[12] tells us:

> In his effort to bring prices down to what he considered a normal level, Diocletian did not content himself with such half measures as we are trying in our attempts to suppress combinations in restraint of trade, but he boldly fixed the maximum prices at which beef, grain, eggs, clothing and other articles should be sold, and prescribed the penalty of death for any one who disposed of his wares at a higher figure.

[11] The population of the whole of Attica at this time was about 500,000, of which Athens comprised about 180,000.

[12] Abbott, Frank Frost: "The Common People of Ancient Rome." New York: Scribner, 1911. Pp. 150-151.

Prices are specified for between seven and eight hundred different items—practically all the articles which his subjects would have occasion to buy. Wages also are fixed—teachers, advocates, bricklayers, tailors, weavers, physicians—all are included. "The carpenter and joiner are paid by the day, the teacher by the month, the knife grinder, the tailor, the barber by the piece and the coppersmith according to the amount of metal which he uses." Abbott calls attention to the fact that the prices given in the Edict are not normal but maximum. As the prevailing prices were so high, however, it is not probable that the maximum prices differed very greatly from them. The net result was failure, and the law had to be repealed because of its impotence in correcting the condition of affairs. Lactantius[13] in 314 A. D. writes as follows of Diocletian and his Edict:

> After that the many oppressions which he put in practice had brought a general dearth upon the empire, then he set himself to regulate the prices of all vendible things. There was also much blood shed upon very slight and trifling accounts; and the people brought provisions no more to markets, since they could not get a reasonable price for them; and this increased the dearth so much that at last after many had died by it, the law itself was laid aside.

The historian Gibbon[14] tells us that sixty years after Diocletian's effort to control the cost of living by fixing prices, the Emperor Julian made a similar attempt, with no greater success. He writes:

> The inclemency of the season had affected the harvests of Syria; and the price of bread in the markets of Antioch had naturally risen in proportion to the scarcity of corn. But the fair and reasonable proportion was soon violated by the rapacious arts of monopoly. In this unequal contest, in which the produce of the land is claimed by one party as his exclusive property; is used by another as a lucrative object of trade; and is required by a third for the daily and necessary support of life; all the profits of the intermediate agents are accumulated on the head of the defenseless consumers . . . When the luxurious citizens of Antioch complained of the high price of poultry and fish, Julian publicly declared that a frugal city ought to be satisfied with a regular supply of wine, oil and bread; but he acknowledged that it was the duty of a sovereign to provide for the subsistence of his people. With this salutary view, the emperor ventured on a very dangerous and doubtful step, of fixing by legal authority the value of corn. He enacted that in a time of scarcity it should be sold at a price which had seldom been known in the most plentiful years; and that his own example might strengthen his laws, he sent into the market four hundred and twenty-two modii, or measures, which were drawn by his order from the granaries of Hierapolis, of Chalcis and even of

[13] Lactantius, L. C. F.: "A Relation of the Death of the Primitive Persecutors." Written originally in Latin. Englished by Gilbert Burnet, D.D. Amsterdam: 1687. Pp. 67-68.

[14] Gibbon, Edward: "The History of the Decline and Fall of the Roman Empire." N. Y.: Fred de Fau, 1906. Vol. 4, pp. 111-112.

Egypt. The consequences might have been foreseen and were soon felt. The imperial wheat was purchased by the rich merchants; the proprietors of land, or of corn, withheld from that city the accustomed supply; and the small quantities that appeared in the market were secretly sold at an advanced and illegal price.

Thus ended Julian's attempt to arbitrarily fix prices. It should be noted that both in the case of Diocletian and Julian the effect of the price fixing was the withholding from the market of the needed food, making necessary the abrogation of the laws by which the prices were fixed.

Great Britain: 1199-1815[15]

Litman[16] in his "Prices and Price Control in Great Britain and the United States during the World War" tells us that "an attempt to control both the wholesale and the retail price of wine by fixing a maximum was made by the British Government in 1199. The measure failed, and in 1330, after a long period of ineffectiveness, a new law was passed which required the merchants to sell at a 'reasonable' price, the latter to be based on import price, plus expenses. This new measure of control proved as futile as the old one."

The first attempt to regulate the price of wheat and bread was made in 1202. The most important ordinance on the matter was 51 Henry III. This ordinance fixed changing weights for the farthing loaf to correspond to six penny varieties in the price of the quarter of wheat from 12 pence to 12 shillings. The law was enforced locally on sundry occasions, but fell gradually into disuse.

Not until 1815, however, were the last laws fixing the price of bread repealed, after a continuous existence of five and a half centuries. The official document [17] recommending their repeal enumerates the ways in which these laws have worked out to show that their repeal is in the interest of the public welfare.

The Dutch Republic: 1584-85

John Fiske[18] in one of his essays ascribes the downfall of the

15 The English corn laws from 1804 to 1846 furnish probably the best known instance of governmental attempts to stabilize prices in more modern times. The corn statutes of these years are simply a record of the impotence of legislation to maintain the price of a commodity at a high point when all of the natural economic forces in operation are opposed to it. *Encyclopedia Brit.*, 11th ed., Vol. 7, p. 177.

16 Litman, Simon: "Prices and Price Control in Great Britain and the United States during the World War." N. Y.: Oxford Univ. Press, 1920.

17 Great Britain, Parliament, House of Commons: Report from the committee of the House of Commons on laws relating to the manufacture, sale and assize of bread. 6 June, 1815.

18 Fiske, John: "The Unseen World and Other Essays." Boston: 1904. p. 20.

Dutch Republic in 1585 to the bungling price-fixing legislation of the government. He says:

The turning point of the great Dutch revolution, so far as it concerned the provinces which now constitute Belgium, was the famous siege and capture of Antwerp. The siege was long and the resistance obstinate and the city would probably not have been captured if famine had not come to the assistance of the besiegers. It is interesting to inquire what steps the civic authorities had taken to prevent such a calamity. Finding that speculators were accumulating and hoarding provisions in anticipation of a season of high prices, they affixed a very low maximum price to everything which could be eaten, and prescribed severe penalties for all who should attempt to take more than the sum by law decreed. The consequences of this policy were twofold. It was a long time before the Duke of Parma who was besieging the city succeeded in so blockading the Scheldt as to prevent ships laden with eatables from coming in below. Corn and preserved meats might have been hurried into the beleaguered city by thousands of tons. But no merchant would run the risk of having his ships sunk by the Duke's batteries merely for the sake of finding a market no better than many others which could be reached with no risk at all. The business of government is to legislate for men as they are, not as it is supposed they ought to be. If provisions had brought a high price in Antwerp they would have been carried thither. As it was the city by its own stupidity blockaded itself far more effectually than the Duke of Parma could have done.

In the second place the enforced lowness of prices prevented any general retrenchment on the part of the citizens. Nobody felt it necessary to economize. So the city lived in high spirits until all at once provisions gave out and the government had to step in again to palliate the distress which it had wrought.

In this way a bungling act of legislation helped to decide for the worse a campaign which involved the territorial integrity and future welfare of what might have become a great nation performing a valuable function in the system of European communities.

India: 1770 and 1866

The famines of India are prominent features in her history. William Hunter[19] in his remarkable book entitled "Annals of Rural Bengal" writes:

Lower Bengal gathers in three harvests each year; in the spring, in the early autumn, and in December, the last being the great rice crop, the harvest on which the sustenance of the people depends. The December crop failed utterly in 1770 and fully a third of the population died. This disaster stands out in the contemporary records in appalling proportions. It forms indeed the key to the history of Bengal during the succeeding forty years.

In 1770 the government by interdicting what it was pleased to term the monopoly of grain, prevented prices from rising at once to their natural rates. The province had a certain amount of food in it and this food had to last nine months. Private enterprise if left to itself would have stored up the general supply at the harvest with a view to realizing a larger profit at a later period in the scarcity.

[19] Hunter, William W.: "Annals of Rural Bengal." Ed. 7. London: Smith, Elder & Co., 1897.

Prices would in consequence have immediately risen, compelling the population to reduce their consumption from the very beginning of the dearth. The general stock would thus have been husbanded and the pressure equally spread over the whole nine months instead of being concentrated upon the last six. Instead of this the government in 1770 prohibited under penalties all speculation in rice. A government which in a season of high prices does anything to check speculation acts about as sagely as the skipper of a wrecked vessel, who should refuse to put his crew upon half rations.

Very different was the procedure of the government at the time of the famine of 1866. Far from trying to check speculation, as in 1770, the government did all in its power to stimulate it. In the earlier famine one could hardly engage in the grain trade without becoming amenable to the law. In 1866 respectable men in vast numbers went into the trade; for the government by publishing weekly returns of the rates in every district rendered the traffic both easy and safe. Every one knew where to buy grain cheapest and where to sell it dearest and food was accordingly bought from the districts which could best spare it and carried to those which most urgently needed it.

In 1770 the price of grain, in place of promptly rising to three halfpence a pound, as in 1865-66, continued at three farthings during the earlier months of the famine. During the latter months it advanced to two pence, and in certain localities reached four pence.

Colonial United States: 1633-1779

Passing now to the eighteenth century some observations will not be amiss on the price-fixing measures resorted to in our country during Colonial days and the early years of the Republic, and also in France during the tragic period of the French Revolution.

Both of these periods have been so ably described that little seems necessary except to give the references to the literature. Winthrop[20] tells us, in 1633:

> The scarcity of workmen had caused them to raise their wages to an excessive rate, so as a carpenter would have three shillings the day, a laborer two shillings and six pence, etc.; and accordingly those who had commodities to sell advanced their prices sometimes double to that they cost in England, so as it grew to a general complaint, which the court, taking knowledge of, as also of some further evils, which were sprung out of the excessive rates of wages, they made an order that carpenters, masons, etc., should take but two shillings the day, and laborers but eighteen pence, and that no commodity should be sold at above four pence in the shilling more than it cost for ready money in England; oil, wine, etc., and cheese, in regard to the hazard of bringing, etc., (excepted).

Bolles [21] gives an excellent account of the experiment of price-fixing in the early years of the United States in the attempt to stop the rise in price of the necessities of life, caused by the declining value of continental paper currency.

[20] Winthrop, John: "The History of New England from 1630-1649." Boston: Phelps and Farnham, 1825. Vol. 1, p. 116.

[21] Bolles, Albert S.: "The Financial History of the United States from 1774-1789." Fourth ed. New York: D. Appleton, 1896. Pp. 158-173.

Pelatiah Webster[22] discusses the legal limitation of prices with vigor and lucidity and shows by resistless logic that such legislation defeats its own end in several ways, the most important of which is the withholding of commodities from the market which it inevitably produces.

On December 20, 1777, Sir Henry Clinton, in charge of the British forces occupying New York, made a proclamation[23] as follows:

> Whereas it is consonant not only to the common principles of humanity but to the wisdom and policy of all well-regulated states, in certain exigencies, to guard against the extortion of individuals, who raise the necessaries of life, without which other parts of the community can not subsist; and whereas the farmers in Long Island and Staten Island are possessed of great quantities of wheat, rye and Indian corn for sale, beyond what they want for their own consumption; and it is highly unreasonable that those who may stand in need of those articles should be left at the mercy of the farmer; and whereas it is equally just and reasonable that every encouragement should be given to the industry of the husbandman, and that in all public regulations respecting the price of the produce of his lands, regard should be had to that of the conveniences which he is obliged to purchase, and whereas the present rates at which wheat, flour, rye meal and Indian meal are sold, do vastly exceed in proportion the advance price of those articles which the farmer stands in need of purchasing, and I being well satisfied, from the best information, and most accurate estimates, that the following prices upon the articles above mentioned will be liberal and generous, have thought it fit to issue this Proclamation, and do hereby order and direct that the prices to be hereafter demanded for the said articles shall not exceed the following rates, viz.:
>
> A bushel of wheat, weighing fifty-eight pounds, twelve shillings, with an allowance or deduction in proportion for a greater or lesser weight. A bushel of rye or Indian corn, seven shillings, etc.

The proclamation proceeds to state that the farmer shall declare how much grain he has and if he presume to sell for a higher price than the one stipulated or "refuse to sell the same at those prices, shall be subject to have his whole crop of grain, or quantity of flour or meal, concerning which such offence shall happen, seized and confiscated, and himself liable to imprisonment for such offence."

Davis,[24] in his able and comprehensive treatment of limitation of prices in Massachusetts, gives much information relating to this

[22] Webster, Pelatiah: Political Essays. Philadelphia: Joseph Cruikshank, 1791. Pp. 11-18.

[23] Clinton, Sir Henry: Proclamation, Dec. 20, 1777. (In the Remembrancer; or Impartial Repository of Public Events. Ed. by John Almon. London (Vol. 6): 1778. Pp. 57-58).

[24] Davis, Andrew McFarland: "The Limitation of Prices in Massachusetts, 1776-1779." (In Colonial Society of Massachusetts Publications, Vol. 10. Boston: 1907. Pp. 119-134).

subject in the other states also. Felt[25] gives extracts from the text of the "Act to prevent monopoly and oppression." He also gives the actual prices set for the various commodities, and in appendix 2 gives "prices of grain, etc., appointed by the general court and taken as currency." These prices are of much interest as they go back to 1642 and were legal tender at that time.

Weeden[26] writes in his "Economic and Social History of New England, 1620-1789":

The colonial history of the United States affords many instances of the failure of fixed prices to remedy the evils they were designed to cure. The governor and council of New England fixed the price of beaver at 6s in fair exchange for English goods at 30 per cent. profit, with the freight added. The scarcity of corn which was selling at 10s "the strike" led to the prohibition of its sale to the Indians. Under the pressure of this prohibition the price of beaver advanced to 10s and 20s per pound, the natives having refused to part with beaver unless given corn. The court was obliged to remove the fixed rate and the price which ruled was 20s. An equally fruitless attempt was made to regulate the price of labor. These regulations were inforced for about six months and then were repealed.

France: 1789-1793

As regards the limitation of prices in France during the Revolution, there seems nothing to add to Bourne's[27] discussion of this subject in the *Journal of Political Economy* for February and March, 1919. We can not fail to note, however, that the system failed signally in France as elsewhere, because supplies were withheld from the markets. The producers could not be forced to declare what they had and without this knowledge the government could not prosecute for withholding them. Bourne writes:

The arguments in the convention relative to the matter ran the whole gamut from the principles of economic liberty advocated by the economists of the day to the radical abstractions of Robespierre and his followers, who swept commerce aside by maintaining that "The food necessary to man is sacred as life itself," and "The fruits of the earth like the atmosphere belong to all men."

One of the most interesting of the many suggestions made in the convention was that of Barbaroux who advocated "a plan to form local associations to collect and circulate information about the crops. In other words, for coercion he would substitute cooperation, believing that the French citizens, farmers and merchants included, would not turn a deaf ear to an appeal for common action against the oncoming peril" (famine). Price fixing finally

[25] Felt, Joseph B.: "An Historical Account of Massachusetts Currency." Boston: Perkins and Marvin, 1839. Pp. 170-173, 184-185, 242-245.

[26] Weeden, William B.: "Economic and Social History of New England, 1620-1789." Houghton: Boston, 1890.

[27] Bourne, Henry E.: "Food Control and Price-fixing in Revolutionary France." (*Journal of Political Economy*, Vol. 27, pp. 73-94, 108-209. February and March, 1919).

became one of the characteristic features of the Reign of Terror, and when Robespierre and his councilors passed through the streets of Paris in the carts of the executioners the mob jeered saying, "There goes the dirty maximum."

Summary

The history of government limitation of price seems to teach one clear lesson: that in attempting to ease the burdens of the people in a time of high prices by artificially setting a limit to them, the people are not relieved but only exchange one set of ills for another which is greater. Among these ills are (1) the withholding of goods from the market; (2) the dividing of the community into two hostile camps, one only of which considers that the government acts in its interest; (3) the practical difficulties of enforcing such limitation in prices which in the very nature of the case requires the cooperation of both producer and consumer to make it effective.

Egypt took entire control of the grain trade and saved the people from starvation, but took over the land in return.

China worked out a system of control of supply and demand which kept prices normal. She seems to have been the only country which recognized the whole price question as being a symptom and not the disease itself, and because she recognized this fact seems to have come nearer than any other country to solving the problem of supplying the people with the food they needed at a price they could pay.

Athens regulated the grain trade and set prices by legal enactment, but found herself unable to enforce them.

Rome made a colossal experiment in controlling prices by legal enactment, but it utterly failed.

Great Britain had on her statute books laws fixing the price of bread continuously for more than 500 years. The price of wheat, fish and wine was also regulated, but all such laws were abrogated in 1815, because of their failure to accomplish the purpose for which they were designed.

The Dutch Republic was overthrown in 1585, and at least one historian of note declares that price-fixing legislation was largely responsible for its downfall.

India has learned in the hard school of experience that even in times of famine price fixing is a very dangerous expedient because it removes one of the most powerful checks on consumption, namely, high prices.

The Colonial United States tried the same experiment at various places and times but failed utterly to secure satisfactory results.

Revolutionary France tried the same measures, but the protagonists of the movement perished on the guillotine. The dreary story of France's efforts to limit prices is distinguished from that of the other countries we have noted because of the proposal of Barbaroux to enlist the aid of both producer and consumer in the effort of the government to control the food supply in the interest of the people's welfare. This proposition was not carried out but it furnished the first indication of the goal of cooperation toward which we are still pressing.

THE SCIENCE OF HERODOTUS[1]

By JONATHAN WRIGHT, M. D.
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THERE is an ever-recurring obscuration of the meaning of words as soon as there is much discussion focussed on the conceptions for which they severally stand. One of the most glaring instances of it in modern times is the word history. Two schools of historians some few years back, a decade or two perhaps, fell foul of one another as to just how it should be written. They belabored one another with great fury and, though I don't think it was ever mentioned by either party, it became evident to dispassionate spectators, beyond the pale, that there should be a differentiation of terms. One school should be called annalists, almanac makers Boswell called them in controversy on the subject with Dr. Johnson, and the other school should be known as excursionists, or if there were such a word, "discursionists." Of course the thought occurs to the Spencerian philosopher that here is the law of the evolution of thought in action. Here is differentiation, here is an evolution from the homogeneous to the heterogeneous and we naturally say the history of science is simply a specialty. Naturally too, this time with a little tone of irritated defiance, we declare that scientific methods of writing history must prevail in the history of science. But is this all just so? In the first place the lay historian is at once in revolt. He wants to know which one is to be called the School of History. The man outside the pale makes a hasty retreat, muttering "bigotry, intolerance, nonsense." And the man of science loftily says, "merely an evolutionary phenomenon."

It is quite evidently then not so simple as any of these formularies might lead us by inference to believe. The question arises, Is history literature? Well, one can not be an annalist or an almanac maker type of historian without feeling in duty bound to answer, "Not exclusively," but if he wishes to exclude the "discursionist" he plumply says "Not primarily." Then he has to compromise and amend by adding, not necessarily. Back of all this contention for the name of historian lies the desire of the annalist

[1] References are to the text of Herodotus. Herodoti historiarum, libri IX, ed. H. R. Dietsch (Teubner).

for readers. This is pressing for the lay historian. It has been demonstrated that men of science can be content to be almanac makers despite the knowledge that no one reads an almanac, but the lay historian has been forced to admit that history is literature, a part of it anyhow, whether he is an annalist or a "discursionist." It is founded on the fact that the knowledge of history forms a part of education that the liberal conception of the latter calls for the diffusion of knowledge as well as its revelation, and on this they base their excuse for bidding for readers. A history that is not read, whether it be of science or of comedy, falls so far short of any one's conception of history that there would seem to be little left to discuss as to who are historians and who are not. To avoid any further reference to it I may explain at once that under the category of almanac makers I meant to range the paleographers and archivists, the pure researchers of history, who make no pretence and have no claim to belong to literature at all. There is plenty to say for them, as much as for the monks and fanatics of all sorts who have or believe they have a grasp on facts and realities that entitles them—and they are right, it does entitle them—to be ranked among the benefactors of the human race. If they really insist that to them and them only belongs the title of historian, I for one out of pure gratitude will gladly serve on a committee to elect some new term to include the "discursionist" in the ranks of those whom we have to call historians, for how are we going to shut Herodotus out? How are we as researchers of science, turned historians, going to justify ourselves for cutting ourselves off from the reading public? The public doesn't read the best literature, it is true; they read poor literature, but poor literature even would soon perish from the world if it were not an humble stepping stone to good literature. Destroy the Queen of the Hive and there are no more bees. Whether it is good literature or bad literature, how is the historian of science to take his important part in any scheme of education unless he reaches the average man of science, the man of science in the street, unless he writes some kind of literature, good or bad, which *attracts?*

It is true that one need not be an excursionist to attract. Thucydides was no excursionist, surely not a "discursionist," and when we read Herodotus and Thucydides we perceive the schismatic feuds of the historians in our day really began with them. We see it is not so much a phenomenon of cultural evolution as an example of two ways of arriving at the same end—the arrest of the attention of busy men long enough at least to instil into their minds something they much need.

All that is good in either method enters by right into any

scheme of education, but the writer who takes no care to attract, makes no effort to allure readers, does not belong to it at all. Charles Booth, the greatest benefactor of humanity, the greatest propagandist of the faith in the 19th century, shrewdly said he did not know why the devil should have a monopoly of the best tunes—those that most move the minds of men—and there is no reason why the propagandists of science should not fall in line with what the minds of men crave as well as the Salvation Army.

I can not linger to point out how these archetypes of the modern genus historian differ, but as between the Prince of Annalists and the Prince of Excursionists, Science can not be long in choosing. Meager indeed are the facts the modern man of science can glean from the fascinating pages of Thucydides, but in those of Herodotus even the modern ethnologist and anthropologist will find information worthy of his attention. Geography and geology quite evidently occupied the thoughts of thinking men of the golden age of Greece. It is not only biology and physiology and climatology which may receive hints from his discourse, but more than all, ethics and the science of moral philosophy, the wisdom of the world, that which is science but vastly more than science, forms a veritable mine open to him who meets it with an open mind. If the historian tells us this is not history, these are excursions and diversions, let us not for a moment imagine that they are not history for the historian of science. We can afford to let the ever smouldering feud go on in lay circles as to whether this thing is and that thing is not history; if the Father of History is no father of theirs, we can only think of the wisdom of the child in recognizing his male parent, which some historians of a recent day do not possess. It is these very excursions, this very discursiveness, the digressions from the path of the story, almost unknown in the tense, vivid pages of Thucydides, which give value to the books of Herodotus as a source for the history of science. These are the things which are history for us and these are the things which, by virtue of their attraction to all men as resting places, if as nothing else, have preserved to us the work of Herodotus for more than two thousand years. Not these diversions alone but pure gossip and idle tales coax the footweary along the central highway. Primitive man is incapable of any other kind of journeys into things intellectual. Assiduity and concentration of mental efforts and, of all things, persistence and patience are acquired virtues and fundamentally that is the reason the pages of Herodotus have been preserved to us and have preserved their charm for the children of primitive men to this day. It is after all the natural way to acquire knowledge. Man picks up most copiously and most to his

advantage those things he absorbs incidentally as he moves to other destinations.

I shall elsewhere have an opportunity to show that Herodotus deliberately and as a matter of art adopted this discursiveness into gossip and tales from the Arabian Nights, but he had no idea that he was departing at all from the true functions of history in his discourse on the geology and cosmogony of Egypt or on the ethnology of the tribes that trooped along behind Xerxes and his Medes and Persians into Greece from all, even the remotest corners, of the known world, perhaps even not when he relates[2] that in Libya lambs come forth at once horned. He shades the phrase just enough not to assert they are born with horns but allows the reader to join with him in the doubt whether or not the genital canal of the mother is in danger of laceration from her offspring. We however forgive the inexactitude of statement when he takes up the discussion of the seasons for this precocity in sprouting horns. He suggests that in these warm climates they grow more quickly. In rigorous climates of severe cold the cattle at first either do not grow horns at all or grow them with difficulty. For my part as a reader of history I halt with pleasure from the bloody murderings of savage men and the sordid rascalities of ancient politicians. It is a digression that rests me and informs me and pleases me, because in this epoch when an era of biological theory has closed and another one has been ushered in, when evolutionary theories are fighting desperately for survival, it brings to my consciousness that man was busy with such thought at the dawn of written records. Apparently Herodotus thought it a legitimate digression. When however he turns to mules he does apologize for the digression. They are so different from lambs, I suppose, but he apologizes in a way that shows these digressions, as I have said, are a part of the art of history writing for him. "The plan of my work from the beginning has sought digressions," he says in parenthesis.

I desire also to show that he grouped all such phenomena in an etiology of environment. He breaks into his story of the northern people with an animadversion to the Libyan phenomenon. Then he switches back to the Chersonese again as though the mule observation reminded him of another example elsewhere ranged under the same law. "I wonder," he says, "that in the whole territory of Elea they can not breed for mules, the climate being neither cold, nor any other cause to account for it," and then he tells what the Eleans themselves say, which is trivial, but the passages allow us to see how the climate as an etiological factor lingers in his

[2] IV, 29.

mind as it did in that of Hippocrates, and caused him to write the wonderful book on climates—Airs, Waters and Places. They were both but voicing the thought of their time. Again it recurs in Herodotus.[3] The Persians, modern archeological criticism has fairly well shown, were descended from northern people, come down to territories below the Caspian Sea evidently from around the eastern end of the Black Sea, more than a thousand years before the time of Herodotus perhaps, on their way to India. The Medes and the Persians stayed behind in a temperate climate and by the time of Xerxes they ruled the tropical tribes of Africa and India and many others and Xerxes laid his conscription on them all and led the most heterogeneous levy of men ever marshalled under one command across the Hellespont. But long before these events there occurred a battle in Egypt between the forces of the Persian King Cambyses, led by the Greek renegade Phanes, and the Greek auxiliaries aiding the Egyptians who were put to flight. This battlefield, some seventy years afterwards perhaps, Herodotus viewed: "I saw a wonderful sight which the people dwelling near told me of. The bones of the Persians lay separately in one place as they stood separately in the battle; elsewhere were the bones of the Egyptians. The skulls of the Persians were so weak that if you struck them once with a stone you would make a hole in them, but the skulls of the Egyptians were so strong you could hardly burst them pounding them with a stone." The old jokes about the thickness of the negro's skull used to pervade the minstrel shows of my youth. Perhaps one can occasionally find them in the funny columns of the newspapers now, but I have really forgotten whether modern anatomical science has given its countenance to them, though I am under the impression that it has. At least modern archeology has shown how large a mixture of pure negro blood there was in the ancient Egyptians. If the joke was of hoary antiquity in Herodotus's day, how modern is his discussion of it! He says this marvel he saw himself, so evidently he was not acquainted with the end man's jibes and repartees and therefore perhaps he was the first to contribute this observation to biological science. The etiological theories of his day may not all of them be admitted to be legitimate claimants to a place in modern discussions, but orthodox or heretical as it may seem to one or the other of modern disputants there is no doubt of the modern plausibility of the one Herodotus chose to transmit to us as the one he thought most reasonable.

"They say the cause of this is, and I readily believe them, that the Egyptians from their childhood up shave their heads and

[3] III, 12.

the bone"—(mark the singular, not the "bones")—"is thickened in the sun. This it is and not because they are bald (naturally) for any one may see that the Egyptians are the least bald of all men. This is the reason the thick skulls belong to them, and as for the Persians, this is the reason they have weak skulls—they grow up in the shade wearing woolen tarbooshes. These things I saw there and others like them I saw at Papremis in those perishing with Achaemenes, the son of Darius, at the hands of Inarus, the Libyan."

Now the battle in which Phanes saw his children sacrificed before his eyes, and Papremis also, may have been great battles, but Herodotus was unconsciously formulating the grounds of a discussion from which in the last hundred years have arisen conflicts, doubtless not so bloody, but not inferior in ardor nor lacking in acrimony and vastly more persistent. Is it the primeval unvarying germ plasm of the negro race or the sun that curls their hair and thickens their skull? Is it climate that starts the lambs' horns to growing in utero? Has not the climate something to do with success in mule breeding? Have we arrived at a satisfactory understanding of the influence of environment on the heredity of man or beast? Those skulls lay heavy on Herodotus's mind, when he spoke of the "bone" of the skull, for he knew well there was more than one usually. He remarks[4] that at the battle of Platæa a Persian fought, whose skull was all one piece of bone, gums and teeth making a solid continuity. The man was five cubits high (7½ ft.?). Aromegaly? I am not an anatomist or pathologist enough to know what it was Herodotus marvelled at, but there can be no doubt he was an acute observer, and a more competent reader than I, if he comes to be as sympathetic toward Herodotus as I am, will easily be able to tell what lesions of giantism confronted him. Elsewhere he several times alludes to the giant stature of individual Persians, some of them, I think, a little exceeding five cubits, but nothing unbelievable in this connection. In these citations of his contributions to this early discussion of evolutionary points I can go no further, nor can I linger long in the few other fields I shall venture to touch upon. I can only seize upon a few of the phenomena Herodotus was interested in, more especially those which lend themselves most readily to a transportation to modern attention. Many fields I have not entered at all here, to which the historian of science may revert with profit.

It is, however, in other fields of science that Herodotus has made the most valuable contributions to its history. These are especially marked in ethnology and to a certain extent they have

[4] IX, 83.

been utilized by some writers, but although much has been left which has not become current knowledge among intelligent men of science I shall not be able more than to touch upon even the ethnology here, and that incidentally to other interests. The question as to how much of the knowledge, lodged in the motley nations of men who dwelt in the basin of the Mediterranean, had been derived from the inhabitants of the hinterland is a matter of great interest. On the whole it has been minimized, I think, rather than magnified by modern writers. Everything which modern historical research has revealed goes to prove how just was Herodotus's conclusion that the garden lands around the Mediterranean were being constantly repeopled or rather their peoples were being constantly replenished by the pressure of Scythian tribes in the hinterland, and they in their turn were being pushed down by the Hyperboreans.[5] Of these surprisingly little was known by Herodotus, but it is surprising only in view of his remarks on the mighty host who crossed the Hellespont with Xerxes. No reader can help being moved at the panorama, revealed to us by the Father of History, which stretched out at the feet of the Persian monarch. If Xerxes wept it probably was not so much at the thought they would all be dead in a hundred years, but from a natural emotion, though not altogether an easily defined one, at the spectacle of the throngs of mankind from every known region of the world arrayed under his banners along the shores of the Chersonese which are washed by the Sea of Marmora, where men are still battling for much the same reason that he was leading his myriads into Greece. Of all these Herodotus has something to say and no one can fail to appreciate that ancient knowledge of the tribes of mankind was far from inconsiderable, but it was the acquaintance with the tribes of the regions south and east of the shores of the middle sea that was by far the most extensive. Modern ethnology is continually having revealed to it that the statements of Herodotus as to these are not wide of the mark, forming a most curious and instructive contrast with the trash collected in the volumes of Pliny—a contrast continually intruding on us when we compare the culture of Greece with the bastard civilization of Rome.

Even of far India we get confirmation of his cannibal story from a source two thousand years later. He says[6] the Hindus, living in the far east are nomads and eat raw flesh and kill their relatives before age or disease has spoiled their flavor, accounting it a piety by thus absorbing them to save them from the sorrows and trials and sufferings of this world. Ludovici Varthema, we

[5] IV, 16.
[6] III, 99.

are told,[7] foremost of travellers and adventurers in the 16th century (A. D.), sailing from Bologna, visited Java and brought back the same account. When Sataspes, at the behest of Xerxes, as a punishment for a profligate Persian nobleman who had committed rape on a noble woman, sailed past the Pillars of Hercules and out into the northern ocean he turned south to circumnavigate Africa; the reward he was to receive for accomplishing it was his life. He failed, returned and was impaled. Sailing for months and months to the south down the west coast of Africa he came off shore alongside of some small people clad in garments of palm leaves, who when he came toward them in the ship fled to the mountains. There can be little doubt from Herodotus's account[8] that in his day the pygmies, in whom the world disbelieved for twenty-five hundred years—even after Du Chaillu found them in Central Africa—dwelt by the sea. Necho, king of the Egyptians, had sent the Phoenicians around Africa sailing out of the Red Sea to the southern ocean and then by the north ocean through the Pillars of Hercules to the Mediterranean ports of Egypt. Much of Asia was explored under the orders of Darius the Great, who ascended the throne of Persia about the time Herodotus was born or a little before. He wanted to know something of the Indus and sent Scylax of Caryander to investigate its mouths where it enters the sea. He and his comrades went down the river and sailed across the Arabian gulf, up into the Red Sea to the starting point whence, some hundred and forty years before, the Phoenicians set out for the circumnavigation of Africa at the command of Necho, so it is not difficult to credit the knowledge of Herodotus to the Egyptians and to the enterprise of the great Persian monarchs, so far as his geography and his ethnology are concerned.

"As to this country (of Egypt)," he says, "much of it, according to what the priests tell me, and it seems to me myself to be so, is land which has been a gift to the Egyptians. It appeared to me that the space above Memphis in between the mountains I have spoken of had been a gulf of the sea, just like the plain around Ilion and Teuthrania and Ephesus and the plain of the Meander, if one may compare these small examples with this huge one. For, their rivers also by silting up having formed these territories, not one of them as to extent can be compared to a single mouth of the Nile, and of these there are five. There are other rivers also, not like to the Nile as to size, which show evidence of the great changes they have brought about. Of these I can give the names and not the least of them is the Achelous running through Akarnania and

[7] Boulting, William: Four Pilgrims, N. Y., Dutton, 1922.

[8] IV, 42, 43, 44.

emptying in the sea, which has made a mainland out of the islands of the Echinades," where Missolonghi is now situated on the Ionian Sea. "There is also in Arabia a territory not far from Egypt, a gulf of the sea jutting into it from what is called the Red Sea, long and narrow, as I am about to relate. The sailing distance, starting from the upper end down to the broad sea takes forty days to cover in a boat manned by oars, but the width of the gulf at its broadest is only half a day's sail. There is flood and ebb tide in it every day. I think once there was another gulf and this an Egyptian one somewhere which set in from the northern sea(Mediterranean) toward Ethiopia; that from the south jutting in towards Syria I have just spoken of. Ends of these had bored through towards one another so as almost to meet, but turning aside a little in the interior of the land. If therefore one wished to divert the current of the Nile into the Arabian Gulf what would hinder it from setting up a barrier in the course of twenty thousand years? I should think it might be raised in ten thousand years. Somewhere within this past time before I was born, would not the gulf silt up and much more, the river being such a hard working one in this way? I follow the opinion of those speaking thus concerning Egypt and I am very much of that opinion myself, having seen a part of Egypt extending beyond its contiguous territory showing shells upon the hills and sea salt spread on the surface, so that the pyramids suffer, and the sand alone making a hill above Memphis and in this place Egypt being like neither Arabia or Lybia and not like Syria for that is a part of Arabia in which the Syrians dwell."

It is probable that when the Athenian in Plato's dialogue of The Laws declared (II:656) that the arts of life had existed ten thousand years in Egypt he was giving vent to a credulity much greater than that of Herodotus, for the existence of civilization is a very different thing from the existence of the life of man in the delta of the Nile. To strengthen their hold on the social organization fast crumbling to annihilation of the empire before the days of Herodotus, the priests of Sais and of Heliopolis manufactured fictitious chronology very evidently, but geologists of more recent date, of the most recent indeed, have brought the figures the priests suggested to Herodotus within the margin of error which is even at present inevitable. So when Herodotus remarks that these priests of Sais were the most learned men he had ever met, those knowing most of the past history of world events, we may be ready to believe that the science they possessed and which he transmits to us represents no negligible body of knowledge existing at the dawn of written records.

Every once in a while, in journals like the SCIENTIFIC MONTHLY, we get a résumé of the state of geological knowledge in refutation of the story Plato tells in the Timæus as to the lost continent Atlantis. I think the preponderance of this geological opinion is to the effect that there are more reasons to believe it never existed and never sank beneath the waters of the ocean in a mighty cataclysm of nature, that like some of the chronology of the priests of Sais the story of the Atlantis was purely fictitious. According to this it wrought havoc with geography not only far out into the Atlantic but it split the rocks of the Acropolis at Athens and altered the shores of the Mediterranean thereabouts. The preponderating view of the geologists is well set forth in a condensed and non-technical form in a publication[9] of the American Geographical Society of recent date. It is only somewhat less frequently than the refutation there arises some one from the ranks of science to give expression to his belief that the story was founded on a tradition having its origin in some such cataclysmic event. Doubtless the conviction which has gathered strength of recent years that the last ice age, both in Europe and in America, was very much more recent than was believed generally by cosmologists a generation or so ago, has had a stimulating effect on the tendency to find the tale from the Timæus creditable as being founded on geological fact. The dates given by Plato not varying much from those given by Herodotus and confirmed by modern science for the approximate age of the delta of the Nile can not fail to suggest that there was prevalent in Greek science a well-founded belief in this cataclysm. Herodotus lived into the age of Plato and read his histories in Athens and doubtless Plato was familiar with them and there could not have failed being an affinity of relationship between the theories as to the Nile and of that as to the sunken continent. Ten or twelve thousand years before the age of Pericles, it must have been thought there was a different course of the Nile and a huge island or continent outside the Pillars of Hercules and that some cosmic disturbance, wide extending and deep reaching, had brought about the geography of the Nile and the shores of the Mediterranean as we know them.

When the Greek became convinced of the ancient nature of Egyptian civilization and saw the evidence of the recent formation of the delta of the Nile, his fertile mind could not fail of being impressed with the dramatic contrast and the probability of a cataclysmic change which not only had once really occurred, but which had given rise to innumerable fables of feats ascribed to the

9 Babcock, William H.: "Legendary Islands of the Atlantic. A Study in Mediæval Geography," 1922.

gods around the Mediterranean, a suggestion not very happy as to the latter, since primitive man has stocked every corner of the globe with fables. However, it is quite as evident as the recent date ascribed to the last recession of the ice that in a period roughly corresponding to it the Nile, then rolling its fertile floods into some other sea basin, the Arabian Gulf or more probably down the valley of the Congo to the Atlantic, was more or less suddenly checked by some upheaval of terrestrial planes and directed toward the Mediterranean. I do not pretend to any ability to interpret correctly the theories of geologists, but this to the average intelligent man of science of to-day makes a strong appeal, and the facts of history and the fables of antiquity seems to fall in line with it. One can not help being impressed with the coincidence of chronology from so many different sources. What Herodotus says of the land of Egypt, what Plato passes on to us as to the lost Atlantis, the confirmation of Herodotus's report as to the age of the delta of the Nile by modern geology and finally the present advocacy of the recent date for the recession of the ice sheet from temperate European and Asiatic regions—all together they lend an air of probability to the old legend of the Atlantis which has invaded geological opinion itself. Termier's advocacy of it seems well known and recently the article by "Ph. Negris, docteur honoraire de l'Université d' Athénes," in the *Révue Scientifique* for September, 1922, has for its opening phrases the following:

"The tradition of the submersion of the Atlantis has been for a long time relegated to the realm of fables; I shared in this general opinion myself until the American geologists established the time with narrow limits (seven to ten thousand years) which has elapsed since the glaciers have receded."

Then he goes on to set forth in a much more frank and uncompromising way than usual in such articles his belief in the prehistoric existence of the Atlantis and in the general scheme of geological events which accompanied its subsidence into the bed of the Atlantic Ocean. Though he extends the argument far beyond the line possible to an article on the science of Herodotus and his Nile theories, I doubt if geological readers generally, even in this country, will find any new evidence in it, but I instance the article, as I might a number of others, in evidence of the growing interest in phenomena which aroused the same theories in Herodotus and Plato near twenty-five centuries ago, but there exists more to support them in our day than in their own.

CONSCIOUSNESS AND THE SENSE OF TIME

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IN recent decades the progress which has been achieved towards the mechanistic interpretation of life-phenomena has been truly startling in its magnitude. Not only have the more obviously mechanical aspects of life been largely traced to the interaction of physical and chemical factors or analyzed into component parts which may be clearly perceived to originate in physical and chemical phenomena, but even those activities of the higher animals, which we were formerly disposed to attribute to the operation of psychic factors, have been so frequently analyzed into mechanistic components that many biologists are beginning to feel that in the interpretation of life-phenomena psychic factors are wholly superfluous. Thus the tropism theory of Loeb, which reduces the directional or "oriented" reflexes of animals to the operation of asymmetric muscular tensions; the older investigations of Fabre, which showed that the elaborate "instincts" of insects represent so many series of concatenated reflexes, directional or other, each reflex affording the stimulus which awakens the next; the investigations of Pawlow, which have shown that "associative memories" are spatially distributed in the central nervous system of the dog in a fashion which corresponds to the spatial distribution of its skin-receptors; the investigations of Cannon, which have traced the expressions of emotion to the operations of chemical excitors or hormones—all of these and many other investigations unite in eliminating consciousness from the group of factors which we have ascertained to be determinative in animal existence.

Now this is a very strange thing, because it is impossible to postulate mechanism without at the same time postulating a percipient consciousness. It is quite useless to attempt to evade this fact. To wilfully disregard consciousness, as something lying outside the real world of scientific investigation, is not to deprive it of existence. If it is a mere illusion, how shall we trust it to enable us to understand those things which are not illusory? The more perfect our mechanistic interpretation of nature becomes, the more utterly do we rely upon the verity and reality of consciousness. It becomes, in fact, our sole prop and stay.

There have been many philosophers and some biologists who, following the path indicated by Berkeley, have not hesitated to ascribe reality solely to consciousness, so that the whole exterior world is viewed as a complex tissue of states of the percipient consciousness. Mechanism in that case would become identical and coextensive with consciousness. But to this theory there is the familiar answer that there is not only one percipient consciousness, there are many. It is true that we can not directly experience the consciousness of any other individual, and, perhaps, from the point of view of a physiologist, it is conceivable that all other individuals except himself might be successfully interpreted as unconscious automata. But this has never commended itself as a reasonable viewpoint, and it is universally conceded that a legitimate argument from analogy justifies us in assuming the existence of multiple discontinuous consciousnesses.

Furthermore, the fact that our perceptions of the outside world are wholly expressed in terms of states of consciousness (for example, color, which has no existence as such in the physical universe), does not in the least controvert the fact that the exciting cause of these states of consciousness lies outside consciousness itself. In other words, there is a reality without as well as a reality within, so that although the reality within, the subjective real, can not perceive the reality without, yet it can perceive the effects of that outside reality upon itself.

A great many contemporary biologists, perhaps the majority of them, are either tacitly or confessedly "monists" of one variety or another. That is, they believe that the universe is one thing, either matter or some other primal entity comprehending consciousness and matter within itself. It is true that pure materialism leaves consciousness unexplained, while it utilizes consciousness to construct its thesis, so that it is logically indefensible. Psychomonism, as we have seen, lands in less obvious, but not less real absurdities. "Psycho-physiological parallelism" states a fact or an assumption, but leaves the fundamental question of unity or duality without an answer. Nevertheless the hypothesis of monism continues to claim a large number of adherents because it receives very substantial support from two independent lines of reasoning and research, which converge towards the same conclusion.

The increasing insistence upon the importance of "subconscious" mental activities by students of psychology and psychological pathology has inspired a number of contemporary philosophical generalizations, of which Bergson's doctrine of "creative evolution" may serve as a type. These hypotheses emphasize the

importance and value of the instinctive and intuitive states of consciousness at the expense of the ratiocinative. Ethically, such doctrines are capable of being construed in a very dangerous fashion. They commend themselves to those who prefer the rule of impulse and emotion to the rule of reason. They set the archipallium above the neopallium. They render the latest acquisitions of man's evolution useless or positively harmful. They lead us away from occidental thought into the mystical regions of oriental speculation. They constitute a denial of the right of reason to rule and direct, and therefore they cut at the root, not merely of our material progress, but also of our social organization, a fact which anti-social elements have not been slow to grasp.[1] We, that is to say the scientific investigators, who have pinned our faith to the contrary supposition, are therefore entitled to scrutinize very narrowly the assumptions which lie at the foundation of these philosophical ideas, and to inquire whether the facts really compel the deductions which have been so freely and fearlessly drawn from them.

Fundamentally, I believe the chain of reasoning which is held to prove the bankruptcy of reason runs something like this: Observations under hypnosis, and in conditions which are probably allied to hypnosis, have revealed the recoverability of vast stores of memories and experiences, of the existence of which we are normally unconscious. Now, at this point a very natural assumption is made, without which the whole subsequent superstructure of reasoning falls. Since memories are customarily associated in our experience with consciousness, it is assumed that those memories of which we do not possess a *waking* consciousness are nevertheless associated with some different or "subliminal" type of consciousness. Since these memories are demonstrably far more extensive than our "waking" memories, therefore, also, this "subconsciousness" is much more extensive than our waking consciousness, and by a natural association of the idea of capacity with that of potency, it may also be supposed to be more fundamental and more important.

Alone, this argument might have failed to carry conviction to the minds of its originators. It received striking support from a much older school of thought, however, and the coincidence of two arguments sufficed to accomplish that which neither would have been able to perform unaided.

The origin of consciousness has engaged the imagination of philosophers and the more philosophical types of scientific men

[1] Lothrop Stoddard: "The Revolt against Civilization," 1922, p. 162.

from a very remote period of history, and some form of pan-psychism, or theory of the universal distribution of consciousness in matter, has been regarded by very many, in every generation since the fifth century B. C.[2] as a hypothesis possessed of a respectable degree of plausibility. With the realization of the fact of organic evolution, this hypothesis sprang to the forefront of importance, for it seemed to furnish a means of accounting for the evolution of consciousness in a series of gradations paralleling the gradations of material evolution. But, if consciousness has been evolved in this manner, then it must exist in some rudimentary and generalized form in every atom, and in a somewhat more specialized form in amoeba until, rising by successive stages of specialization, it finally attains the degree of complexity and self-awareness which we subjectively experience within ourselves. Now our waking consciousness is lost in profound sleep, or as a result of relatively trivial lesions in a very restricted area of the brain. Our organization is not rendered appreciably less intricate, and so, if intricate organism implies a parallel intricacy of consciousness, there must be a vast realm of consciousness of which we are normally unaware, *i. e.*, a "subconsciousness."

Now we must note the precise implication of this hypothesis, which is at first sight so simple and so plausible. The only consciousness of which we are ever normally aware is that minute fraction (as we must suppose it to be, if the above reasoning is correct) which constitutes our *waking* consciousness. To account for this, however, we are inventing a whole spectrum of states of consciousness, of which only a minute proportion is visible to us. In the physical spectrum there are certain gaps which have not as yet been rendered visible to us by the artificial senses of science, but the areas which have become visible form so large a proportion of the whole, and are so widely dispersed within it, that we are undoubtedly justified in assuming that the physical spectrum is truly continuous. But what would we say to the physicist who, having caught a glimpse of the sodium lines, were to straightway declare "From this I infer the existence of a continuous spectrum, from the infra-red to the x-rays?" This "reasoning," so obviously reckless in the physical world, has not infrequently been accepted as valid by biologists such as Driesch and Verworn and philosophers such as Bergson. Their unquestioning faith doubtless arises out of the difficulty of conceiving any other origin of waking consciousness *if we suppose that consciousness has been evolved*. But is this supposition really necessary?

[2] G. S. Brett: "A History of Psychology," London, 1912, Vol. 1, p. 32.

The alternative supposition to which the phenomena of "subconscious memory" might conduct us is simply this: *Memory is not always associated with consciousness of any kind, although it may occasionally be illuminated by consciousness.* Why, indeed, should we prefer the self-contradictory assumption of the existence of forms of consciousness which are not conscious, to the entirely self-consistent hypothesis of a purely unconscious mechanism of memory?

Memory is, in fact, no mysterious thing which is inexplicable in mechanistic terms. On the contrary, a twisted bar of steel may readily be shown, by the phenomena of hysteresis, to have "remembered" the torsion to which it has been subjected. Its behavior for long afterwards is modified by its "experience." I have elsewhere[3] proposed a theory of memory in animals which attributes this phenomenon to chemical changes in nerve fibrils which facilitate the subsequent passage of impulses along paths which have previously been traversed. The process of memory "trace-formation" would thus be essentially a process of autocatalysis, analogous to many other autocatalytic phenomena which occur among the activities of living organisms. Would it not be better, therefore, to place the more obvious interpretation upon the facts, and regard consciousness as a species of searchlight, illuminating a minute fraction of the vast void of blank unconsciousness in which our mechanisms move and have their being? This consciousness, which we may define as *the awareness of its content,* may illuminate at one moment a relatively large area of cerebral activity, at another a relatively small area. When it illuminates but a fringe of the horizon of our cerebral life, we are semi-awake or dreaming. When a larger arc is illuminated, we speak of full or "waking" consciousness. When the light descends, as under hypnosis, to the objects and events which lie near at hand, in the most intimate recesses of our cerebral life, then we momentarily view a panorama of events and memories of which the magnitude and variety amaze us, but of the existence of which we are normally oblivious.

A striking experiment, which reveals in the clearest fashion the mechanistic origin of memories and associations, has been performed by Professor I. P. Pawlow.[4] If a dog is shown food, its

[3] T. Brailsford Robertson: *Arch. Internat. de Physiol.*, 1908, VI, 388. "Folia Neurobiologica," 1913, VII, 309.

[4] These experiments have only been described in Russian, and the original descriptions are therefore inaccessible to me. I owe my knowledge of the above particulars to a personal statement and demonstration which Professor Pawlow very kindly gave to me during my visit to Petrograd in March, 1914.

salivary glands secrete saliva, the volume of which may be measured by inserting a tube in the duct of the gland and collecting the drips. If, at the same time that the dog is being fed, we apply some other stimulus, for example, pressure on the skin at some particular point, on repeating this many times over a period of several weeks the dog comes to associate this stimulus with the notion of food, and ultimately secretes saliva when the skin-pressure alone is applied. When the association has been thus established, pressure applied to any part of the skin yields a secretion of saliva. If, now, this stimulus is applied at intervals of half a minute several times in succession without the administration of food, so that the dog experiences a series of disappointments, the secretion of saliva progressively diminishes until it ultimately disappears. On now shifting the point of stimulation quickly to another area, a full secretion is obtained, but if we wait two or three minutes we find that it can not be elicited by the stimulation of that point either. A minute ago the dog possessed a memory associated with stimulation of this part of its skin. In the meanwhile nothing has been done. Yet the memory has lapsed. This loss of memory progresses from point to point over the whole skin, from the hind foot, up the leg, along the flank and down the front leg, arriving at each point a little later than it arrives at the preceding point. A change has occurred in the brain; a wave of forgetting has passed over the area of the brain which corresponds to the tactile sense in the skin, and the motion of this wave is so slow as to occupy several minutes. A few minutes later memory is restored, the effect of disappointment has worn off, and the wave of reawakened memory travels over the same path at approximately the same rate as the wave of forgetfulness. Now we can not suppose the dog to be conscious of all this. If the dog is really endowed with consciousness, which appears a reasonable supposition, then we must suppose that the consciousness of the dog is, in this case, merely a passive registrar of the memories which are formed and dissolved mechanically in its cerebral structures.

The difficulty attaching to a dualistic conception of the universe, which regards the possession of consciousness as some new thing, lodging in animate nature for the first time somewhere about the phylogenetic level of the vertebrates, is that it involves an apparent discontinuity of evolution. I think, however, that those who experience this difficulty are, after all, viewing the phenomena with a monistic bias. They are regarding consciousness as, in some sort, a "secretion of the brain," and, if it appears unheralded in nature, a breach of continuity in evolution is supposed to have occurred. Setting aside, for the moment, the ascertained fact that

organic evolution has actually occurred in a series of discontinuous progressions or "mutations," we may still say that if consciousness be regarded as a thing wholly distinct from matter, which is the point of view of the average layman, then no breach of continuity has occurred when the progress of organic evolution, approaching ever more nearly to the necessary degree of organization, at last intersects the reality of consciousness. To make the matter evident by a more or less imperfect analogy, no breach of continuity in the evolution of human implements occurred at the moment that the invention of the coherer enabled the Hertzian waves to be for the first time perceived by man. The complexity of our physical apparatus had then developed to the extent of intersecting these waves of great length, and henceforth, although without breach of continuity either in nature or in organic evolution, a new mode of perception was vouchsafed to man.

In recent years we have become accustomed to the idea of a space-time reality which, as the students of relativity have taught us, constitutes our physical universe. Now the consciousness-reality evidently intersects the space-time reality along the time-axis and nowhere else. It is extended in time, but not in space. I suggest that this intersection is accomplished by means of a specific cerebral apparatus which "perceives" absolute time. The nature of a machine capable of perceiving absolute time, as the eye perceives light, is not at all inconceivable, and its main characteristics have already been described by students of relativity.[5]

A time-machine would, by its very nature, add no energy to the organism in which it occurred, nor would it expend energy, for energy is invariably associated with mass. It would, however, be capable of influencing the *rate of release of energy*. In that case whatever happened would be a consequence of transformations of material energy, but the moment and rate at which it happened would be subject to influence by the state of consciousness. A signalman, in operating his switches, performs virtually no work, yet he determines out of a mechanically limited choice of possibilities the direction of discharge of all of the vast energy output of the railway engines. In similar fashion our consciousness may, within the mechanical limitations imposed by our cerebral architecture, direct the output of bodily energy, without generating or abstracting any energy itself. At the bifurcation of the paths the time-switch may be thrown this way or that, and, thereafter or before, all that happens is mechanically inevitable.

The cerebrum of man, thus viewed, contains a time-machine

5 A. S. Eddington: "Space, Time and Gravitation," Cambridge, 1921, Chap. 2.

whereby our material entity intersects another reality, and the product of this intersection is consciousness. It is most important, in this connection, to realize that the coordinating activities of the brain do not necessarily involve consciousness. During sleep, or unconsciousness from other causes, bodily activities controlled by nervous agencies may continue uninterrupted. Many of these, for example, breathing, may be injected into the field of consciousness during waking hours, but this is not at all essential. The brain is a self-sufficing machine, with or without consciousness, that is, with or without activity of that latest addition to our cerebral apparatus which brings us into relation with the consciousness-reality through the medium of time.[6]

The sense of time thus becomes at once the most fundamental and the most remarkable of the endowments of man, for it lies at the very root and foundation of our consciousness. I am well aware that some attempts have been made to interpret the time-sense as a proprioceptive sensory perception of the rhythmic processes of the body, such as the heart-beat. It is obvious that such an explanation does not resolve the unique character of time-perception at all, for the receiving mechanism in the brain is presumed to interpret the rhythmic motions in terms of time. What need have we for a heart-clock when we must in any case have a brain-clock in order to interpret it?

This consideration leads us to an objection which has been invariably urged against the dualistic theories of consciousness, and that is the difficulty of conceiving interaction between such diverse things as an immaterial entity and matter. It is this difficulty which has led to the formation of the various views of psycho-physiological parallelism, whereby, for some reason not readily comprehensible, unless we accept the monistic interpretation of Spinoza, the phenomena of consciousness and those of material events march parallel with one another reproducing each other in every minutest respect. But now that we conceive time as one of the dimensions of a space-time entity, and assuming that this entity and the consciousness-entity intersect or coincide in the time-dimension, interaction becomes just as feasible and comprehensible as if they intersected in one of the space-dimensions. It is true that consciousness generates no energy, and therefore contributes nothing to the total energy-output of the body—but interaction without alteration of the output of energy is precisely what

[6] The importance of the time-sense in the evolution of man has latterly been especially emphasized by Korzybski ("The Manhood of Humanity," New York, 1921), but from quite a different point of view to that which has been adopted here.

we should expect if interaction is limited to the time-dimension, because rates and not masses would be the quantities affected. In the language of the chemist, consciousness might be expected to act as a catalysor, affecting only rates of transformation and not the final condition, save to the extent that alternative routes by which equilibrium may be attained may be decided by acceleration of one in preference to another.

It must not be forgotten, however, that this interaction is mutual, and that consciousness finds the receiving apparatus now in one state and again in another, due wholly to bodily events. It is important to realize that these are states or conditions of a machine which are merely registered by consciousness, and that consciousness no more generates the energy of the machine than the brain of the composer generates the electric current which operates an automatic piano. Thus the bodily events are not necessarily disturbed if the registrar of these is absent, as in dreamless sleep, or compelled to employ a grossly imperfect apparatus, as in the insane. Conversely, any interaction of consciousness in the catalytic manner of which the possibility has been indicated, will merely modify the channels or rates of discharge of energy, and the outcome will then be determined by the bodily machine. Hence, whatever their subjective counterpart may be to the individual who displays them, to an *external* observer all bodily activities will appear to originate wholly in the material machine itself, without any interference from consciousness. This does not mean that the existence of consciousness in an organism is necessarily impossible to demonstrate objectively, but it does imply that no act of any organism, conscious or otherwise, can be any other than that which is, under all the given circumstances, mechanistically inevitable.

I suggest that this hypothesis of "mechanistic animism" has a special claim to consideration because it reconciles our subjective experience with the mechanistic generalizations of the physiologist and the idealistic conceptions of reality. Moreover, the difficulty of conceiving the evolution of conscious from non-conscious entities is not encountered, for consciousness has not been evolved by organic nature—it has been discovered.

PASTEUR AND THE SCIENCE OF BIOLOGY[1]

By Professor CHARLES ATWOOD KOFOID
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THE life and work of Louis Pasteur has had fundamental and far-reaching effects upon the direction and progress of the biological sciences. His influence may be traced along two paths—the one a direct road to specific developments such as the emergence and establishment of the science of bacteriology with its daughters, immunology and serology, and the concept of communicable diseases each due to a specific organism.

The other path of influence is less direct, but even more significant in that it turned the thought and effort of investigators in remoter fields into new lines of endeavor and thus shaped indirectly the course of scientific progress. Illustrations of such potent influence flowing from Pasteur to the contemporary and subsequent development of the biological sciences are seen in at least four directions, namely, in the origin of the science of animal parasitology and its relations to human and comparative pathology; in the effect of his disproof of the dogma of spontaneous generation upon the progress of evolutionary thought and the development of genetics; in the establishment of a demonstrated basis for the unity of the biological sciences and their close interrelation with the physical sciences; and in the significance of the experimental method to the biological sciences as a whole.

Thus, indirectly the method and results of Pasteur's work both stimulated and directed the course of development of the biological sciences in many fundamental respects. This was the result alike of his commanding genius and of the human relations of his discoveries along practical and philanthropic lines. His genius created the absolutely necessary scientific basis for his influence, and the applications of his talents to problems of human interest extended that influence far and wide and gave it power not only over specialists but over the minds of thoughtful men generally.

The science of parasitology in relation to disease owes its origin and progress in large part to Pasteur's work and influence, not

[1] Delivered at the Pasteur Centennial celebration at the University of California, February 1, 1923.

only by analogy to bacteriology, but directly. Prior to his successful attack upon the disease of silkworms parasitology was mainly a field for the investigation of the varied fauna of worms in the intestines of vertebrates, interesting to a few helminthological specialists. Pasteur's studies on fermentation and his successful attack upon the doctrine of spontaneous generation inspired him with the idea that communicable diseases were likewise due to germs. Not being a physician his access to these problems in man was for the time blocked. He therefore plunged with great zeal into the attack upon the diseases of the silkworm in the period between 1865 and 1870 and proved to the satisfaction of himself and his scientific friends that the destructive pebrine of the silkworm was an infective corpuscle of microscopic size found not only in the dying worm and sickly moths, but inherited in the eggs of infected moths by the next generation, and found also in some worms and moths showing at the time no signs of the disease. He saved the silk industry for France by this discovery and by his patient and persistent efforts to instruct the conservative French farmers in the practical methods of finding by microscopical examination stocks of moths free from the corpuscles of infection. He exposed ruthlessly the unscrupulous growers and vendors of infected stocks and finally succeeded in establishing standards of purity which saved this industry for his country, and thus paved the way for the prompt payment of the war indemnity of later years to Germany.

Pasteur did not know at the time that the corpuscle which he discovered was not a bacterium but an animal, a protozoan. His discovery was, however, made prior to our knowledge of the existence of those parasitic protozoans which produce disease in man and other animals. It was not until 1880 that Laveran found the malarial parasite in the blood of man; until 1891 that Councilman and Lafleur proved that amœba caused dysentery and liver abscess in man; and until 1902 that Dutton discovered trypanosomes in the blood of patients suffering from what was later proved to be the dread sleeping sickness of African natives and travellers. Pasteur's discovery opened the minds of men to the relations of parasitic organisms in general to disease and showed the possibility that some infections might be hereditary and persistent. He emphasized the parasitic aspect of the pebrine corpuscle, later known as the protozoan *Nosema bombycis*, and paved the way for the later expansion of human and comparative parasitology to its now ever-enlarging relations to pathology and disease.

The dogma of the spontaneous generation of living organisms from dead and decaying organic substances is as old and as per-

sistent as biological speculation. It is even quite impossible to say to-day that it is as yet quite dead. Many biologists even now harbor the hope that the progress of scientific discovery may some day enable man to describe in scientific terms and perhaps even to repeat the conditions experimentally under which the functions of life appear in matter and the simplest forms of life emerge from the non-living world. This process, however, when discovered, will be orderly and a part of the system of nature.

The ghost of spontaneous generation, which Pasteur and Tyndall so convincingly laid, was the belief and dogma supported at that time by reputable experimental biologists that it was possible to produce in dead and putrescent organic material in sealed glass tubes living organisms of known types. Life thus appeared to be derived from the dead material and the idea of the continuity of life was disenthroned. Pasteur proved beyond a shadow of a doubt that the experiments upon which the so-called proof of spontaneous generation rested were faulty in technique and that any organic substance once sterile and afterwards protected from the access of germs remained ever after sterile and free from living organisms of fermentation and decay, and of any kind whatever.

This proof was fundamental to Pasteur's new conception of the germ theory of communicable diseases, to Lister's aseptic surgery and underlies the success of the modern canning industry. It has had, however, far wider influences than these in the fields of biological thought and has determined the subsequent direction and rate of biological progress in no small degree. It proved conclusively the practical point that known forms of life can be produced only from preexistent organisms of the same kind. Not only do figs come from figs, but typhoid germs only from the typhoid bacillus. The firm establishment of this fact so soon after the publication of Darwin's "Origin of Species" rendered great service to the acceptance of the idea of organic evolution by establishing the fact of the orderly descent of organisms, the absolutely essential foundation stone for Darwin's contribution of the idea of descent with modification. At one stroke Pasteur not only unified the organic world, but prepared the way in men's minds for the idea of the unity of all vital processes. A by-product in our own day of this lifting of the incubus of a false dogma from the minds of men is seen in the rapid growth of the study of the mechanism of heredity and the birth of the science of genetics.

In another striking particular Pasteur's work is significant and will be, let us hope, increasingly prophetic for the mode of scientific progress in the future. I refer to the unification in his

attack upon research problems of scientific disciplines now so widely segregated and dispersed in separate compartments of organized science both in scientific education and in research. The rapid progress of science in the last fifty years has carried investigation and investigators into widely divergent compartments, walled off from each other by professional, bibliographical and departmental barriers that effectually prevent interchange of ideas and methods and offer, one might almost dare to say, the most impassable barrier to successful scientific discovery in our university life to-day—hence the growing tendency to establish research institutes where the disciplines separated in the university are united in attack upon common problems.

Pasteur's investigations ranged through nearly the whole gamut of our categories of the physical and natural sciences. He was a chemist, crystallographer, physicist, bacteriologist, mycologist, entomologist, parasitologist, protozoologist, and above and over all an experimental biologist. His life is an example to us all in these days of specialization. We can not turn back the hands of the clock of science to those days of Pasteur's early work when the sciences were simpler and rudimentary, but his results should teach us the value of synthesis as over against specialization and impress upon us the necessity of breadth of preparation in all sciences for effective work in any one of them. Above all, does it teach us the unity of all science and the great value and stimulus which may be derived from their close interrelation in instruction and research. Take, for instance, the first scientific problem attacked by Pasteur, that of the symmetry of crystals. It is fundamentally a problem of the organization of matter and extends from spiral nebulæ in the milky way through crystals to the living world, to the twisted trunk of the fox-tail pine and the left-handed child.

We owe to Pasteur the enthronement of the experimental method in the biological sciences. Without it biology is at the mercy of hypothesis. Pasteur, next to his hatred of falsehood and greed, dreaded nothing more than the possibility that he might be led to conclude that something might be true because he desired it to be true. Scientific prejudice, if this incompatible juxtaposition of words may for the moment be permitted, was Pasteur's *bête noir*, and the experimental method was his salvation. His skillful, simple and convincing use of the method has for all time made it an indispensable weapon in the armament of all of the biological sciences whose assaults every hypothesis must ultimately withstand before recognition can be granted.

Pasteur's life and labors were dominated supremely by loy-

alties, to his parents, to his home, his wife and children, to his teachers, pupils and colleagues, to his country and to his faith and to science. Loyalty was his dominating passion. Service to his fatherland led him to take up so-called practical problems, silk-worm disease, the ailments of wines and beers, the dreaded anthrax of the herds of the French farmer, and typhoid and rabies. This breadth and strength of his loyalties carried him successfully past the Scylla of shortcut and futile methods which lesser men sometimes attempt in the applied sciences and the Charybdis of dehumanized scientific abstraction to which some great minds limit their scientific endeavors and sympathies. For him the truth could be found in both fields of scientific endeavor, the pure and the applied, but his sole aim and goal was invariably the truth, and his method of attack the same in all cases.

Investigators and students in the biological fields will find much to admire and much to learn in Pasteur's methods of work. These were always characterized by the two elements which Poincare has so emphasized in his essay on "The Method of Mathematical Discovery," namely, intensive application to all the details of the problem by direct and repeated examination until his whole being, conscious and subconscious, was absorbed in its contemplation, and secondly the discursive excursions of his creative imagination until the disjunct, diverse and incoherent data began to be assembled in order, and the emerging relations excited those esthetic satisfactions of the intellect which presage discovery. To these two steps Pasteur always added a third, the rigid test, by experiment, of the truth or falsity of every emerging discovery at every vulnerable point, until logic and reason alike approved the conclusion.

To one who reads between the lines of Pasteur's varied and so often successful methods of attack upon difficult problems and finds the ever-recurrent challenge to himself and his colleagues, "Let us all work," one is impressed in it all by his belief in his ultimate success. To him the world was neither chaos nor chance but infinite order and the expression of The Infinite.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson
Science Service, Washington

THE ECLIPSE AND EINSTEIN

The development of a batch of photographic plates is often awaited with impatience and anxiety. In the case of an amateur the impatience is manifested by the snapshotters and the anxiety by his sitters.

But perhaps never before have so many people in all parts of the world been eager to learn "how the plates turned out" as in the case of those brought back from Australia by Dr. W. W. Campbell, the man who observes the movements of the heavenly bodies by night at the Lick Observatory and by day controls the movements of the students at the University of California.

For these negatives taken during the eclipse of September 21 contained the evidence for or against the Einstein theory of relativity which has excited the interest of all astronomers and, for various reasons, an unexpectedly large proportion of the public. The less people understood it the more eager they were to hear about it.

The man who manifested the least anxiety about the results of the eclipse expedition was apparently Einstein himself, for having made up his mind eight years ago how the heavenly bodies must behave he remains serenely indifferent to the efforts of astronomers to find out how they do behave. It followed as a logical deduction from his theory of the relativity of all measurements in space and time that a ray of light passing close to the sun would be drawn out of its straight course as though the light were attracted by the pressure of such a heavy mass. And since the path of the ray is drawn inward toward the sun an observer on the earth looking back up the ray would see the star as though it were moved outward from the sun. If a photograph of a group of stars taken with the sun in the middle is compared with a photograph of the same group without the sun, the images of the stars in the former case will seem to have been displaced from their ordinary positions in the sky. The stars nearest the sun's disk will naturally seem to have moved out the most. The effect is the same as you have noticed when a patron of the bootleggers gets aboard a crowded street car. All move away from him and those nearest the obnoxious individual move farthest.

Nobody had discovered or suspected such a displacement of star images about the sun until Einstein predicted it from his mathematical theory. As figured out from his formula, a ray of starlight just grazing the sun's disk would be deflected toward the sunny side to the extent of 1.75 seconds of arc. The star images further away would be displaced less according to their apparent distance from the sun.

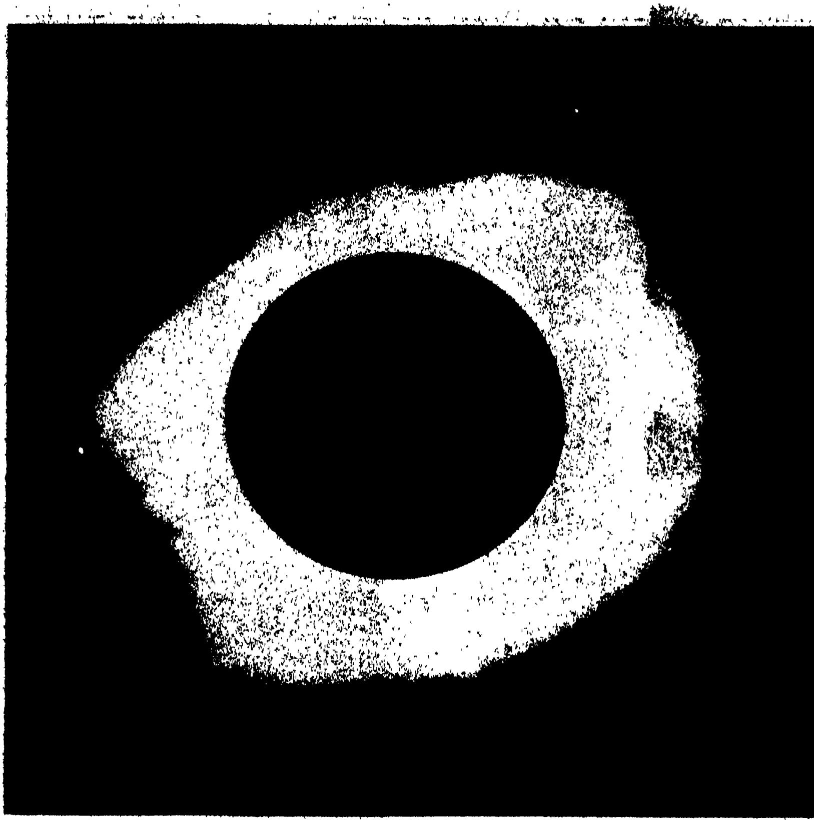
Of course, the stars can not be photographed when the sun is shining into the telescope, so one must wait till the sun is totally shielded from the earth by the moon. The British astronomers took advantage of the first opportunity to put the Einstein theory to the test, the eclipse of 1919, and they came back from South America and Africa with the report that the star images were dispersed as Einstein had predicted. But they had good photographs of only seven stars and have been sharply criticized in scientific circles.

But now that President Campbell has explained to the American Philosophical Society of Philadelphia and the National Academy of Sciences at Washington the results of his observations in Australia there is little

Wide World Photos

THE CROCKER ECLIPSE EXPEDITION

Temporary observatory at Wallal, South Australia, at which the expedition from the Lick Observatory under Professor W. W. Campbell made photographs confirming the Einstein prediction of the deflection of light by gravity and obtained other important results.

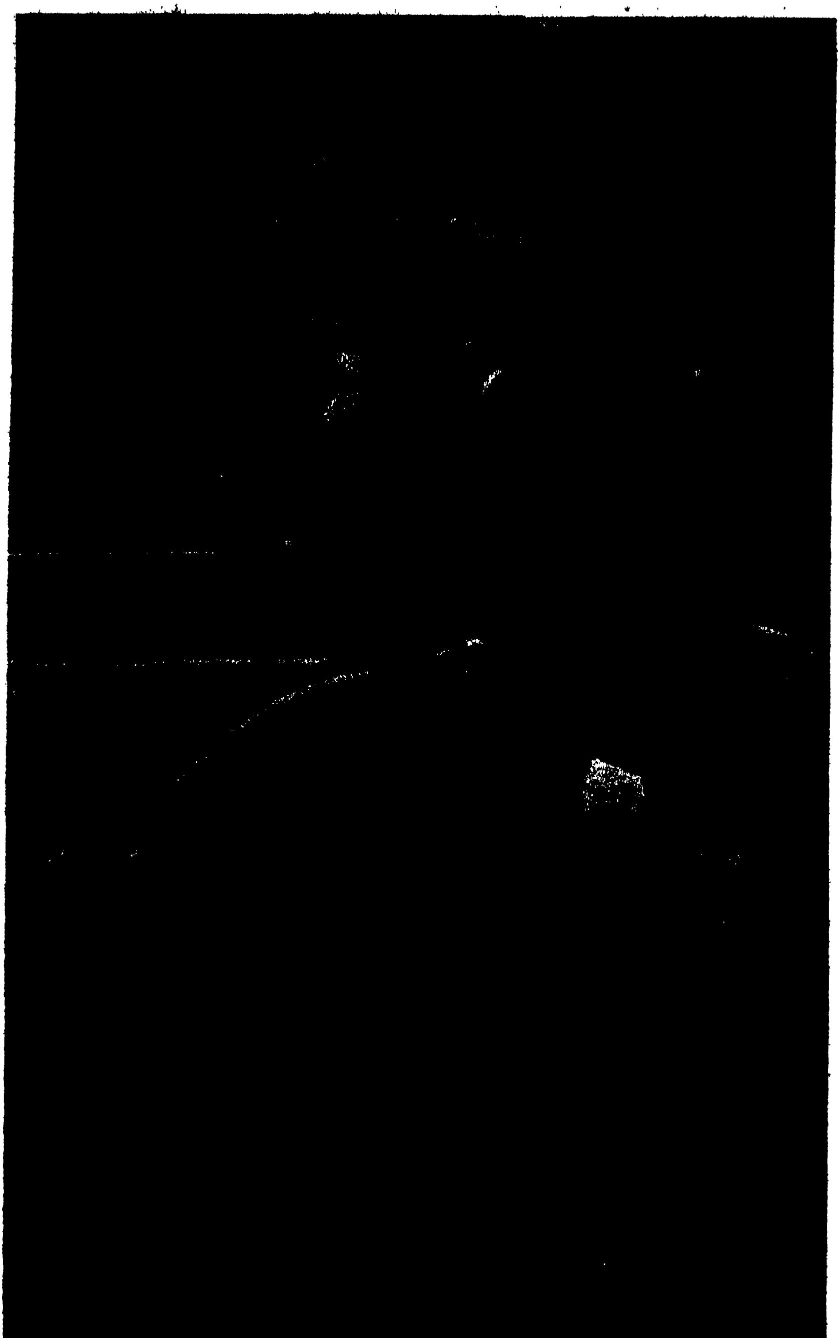


THE SOLAR CORONA
Photograph taken by the Crocker Eclipse Expedition at Wallal.

ground left for skepticism on this point. Instead of seven stars, he has five sets of plates containing from sixty-two to eighty-four star images and when these are measured with the micrometer and calculated to a common position at the edge of the sun the mean is 1.74 seconds of arc, which is almost exactly the deflection predicted by Einstein. The negatives are 17 inches square, and it took Dr. Campbell fifty hours of working time to measure up the stars on a single eclipse plate in comparison with one of the same section of the sky at other times.

The same plates were measured by different astronomers who could not know what the results would be until they were finally figured out. Check plates taken of other stars show that the displacement images can not be due to any defects of the telescope or sensitive plates. The Canadian eclipse expedition also obtained observations confirming the Einstein theory.

So certain does Dr. Campbell feel of these conclusions that the Lick Observatory will not devote further effort to the verification of the Einstein theory, although the next eclipse comes in California on September 10. The British astronomers had previously announced that they would not send out an expedition to observe the coming eclipse if the results of the Lick expedition to Australia last year settled the matter satisfactorily. This it seems to have done, but there are enough other unsettled problems in the relativity theory to keep the scientists busy for many years.



M. EDOUARD BAILLAUD
Director of the Observatory of Paris, on whom the Bruce Gold Medal of the Astronomical Society of the Pacific has been conferred through the American Ambassador at Paris.

COAL OIL FROM COAL

WHEN kerosene first came into use as a lamp illuminant it was called "coal oil," for it used to be supposed that petroleum had somehow been formed from coal. Later that theory was called in question and geologists are still disputing the origin of oil. We seem likely to use it up before we find out where it came from. But even if coal oil turns out to have been an inappropriate name in the past, it may prove to be true in the future. For petroleum can be made from coal and some day we may have to make it that way.

For the less oil we have the more we use. The lower the supply in the ground the higher the output of our refineries. The report of the Bureau of Mines for January comes to my table to-day and I find that twenty million gallons of gasoline were turned out every day on the average, while for the same month in 1922 the output was fourteen million gallons. This increase can not keep up forever, however liberally you may estimate our unseen supply underground.

The countries that are short of petroleum are already contriving substitutes. The Germans, who were well supplied with coal, but had little oil, began before the war experimenting on methods of making artificial petroleum. Since they have lost some of their best coal fields through the war and oil is harder to get than ever, they have been still more active in such research, and it is rumored by returned travelers that they have been more successful in that quest than has appeared in print. What little has leaked out has mostly come through the patents which Freidrich Bergius has taken out in Germany and the United States from 1914 to 1922. But a patent, especially a German patent, is by no means so "patent" as it is supposed to be, so not much is known by the outside world about the details or the practicability of the process.

Theoretically it is simple enough. Petroleum is a mixture of compounds of hydrogen and carbon. Just hitch up these two elements and there you are!

But there are other hitches in the proceedings. Either carbon or hydrogen will unite readily with oxygen, but they have little liking for each other. Only when stirred up by high heat and forced into contact by high pressure will they combine. Besides the expense of the process there is the expense of the materials. Carbon is cheap and abundant enough in the form of coal, but hydrogen has to be obtained by tearing it away from the oxygen with which it is combined in water. This may be done by passing steam over red hot iron turnings which pick up the oxygen and release the hydrogen. Or steam may be passed through beds of hot coal which give what is known as "water gas," a mixture of hydrogen and carbon monoxide, both good combustibles.

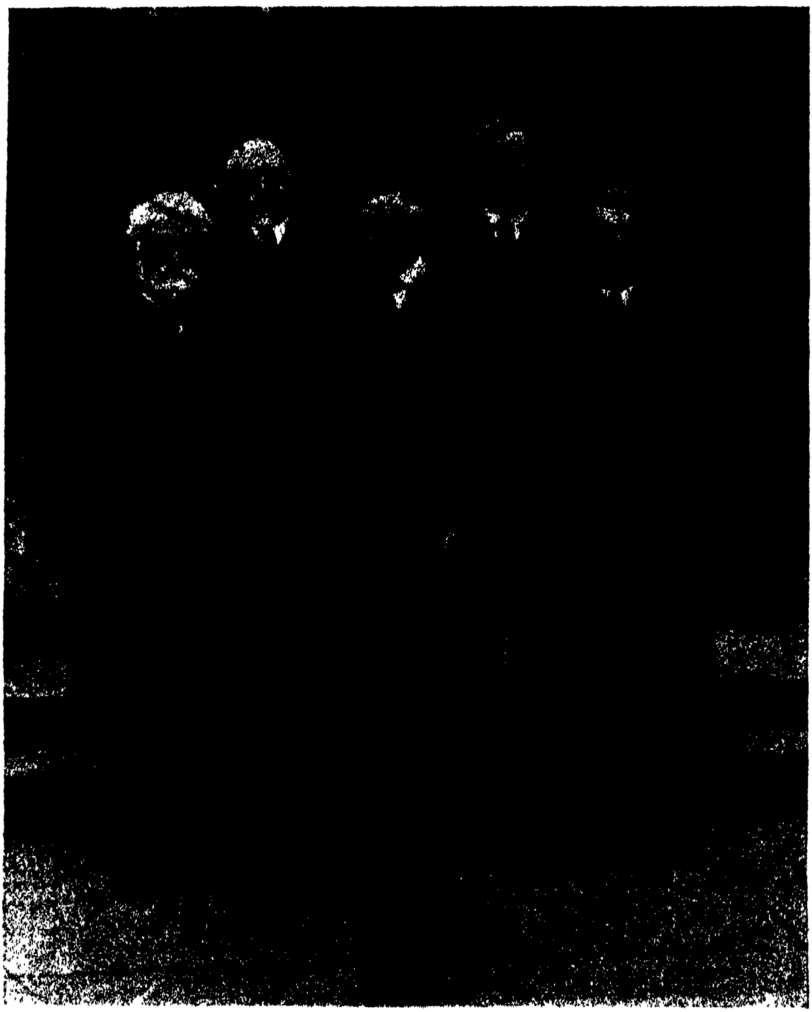
In making synthetic petroleum it appears that the coal is first powdered and mixed with heavy oils. This pasty mess is put into a tight steel retort and a current of hydrogen or water gas is run through the vessel at a temperature of some 700 degrees Fahrenheit and a pressure of a hundred atmospheres.

Under these conditions the carbon and the hydrogen gas unite in all sorts of ways and form liquid products, and an oil much like natural petroleum distills off from the retort. This is redistilled; the lighter fractions collected as gasoline, kerosene, benzene and the like, and the heavy residue returned to the retort and mixed with the next batch of coal.

It is claimed that by such a process as high as 87 per cent. of the carbon in the coal can be converted into liquid hydrocarbons, such as are found in natural petroleum and also the coal-tar products which can be used as material for

dyes and drugs, preservatives and perfumes. The nitrogen in the coal, which is lost in ordinary combustion, is here obtained in the valuable form of ammonia.

The coal for this process does not have to be of a special quality as is required in making gas or coke by our present methods. Any kind or form of coal can be used and high yields of the hydrogenated products are said to be obtained from the brown coal and lignite of which Germany has an abundance. Peat may be thus worked up into gasoline and other marketable compounds, also pitch, tar, sawdust and any vegetable material.



BOARD OF VISITORS TO THE BUREAU OF STANDARDS
Left to right—front row—Ambrose Swasey, of Cleveland, Ohio; F. W. McNair, president of the Michigan School of Mines; Samuel W. Stratton, formerly director of the Bureau of Standards and now president of the Massachusetts Institute of Technology. Back row—John R. Freeman, of Providence, and Wilder D. Bancroft, professor of physical chemistry at Cornell University.

Although there is little likelihood at present that such a complicated process will come into use here so long as our oil wells continue to flow, it is reassuring to know that when they do run out we shall not be altogether deprived of the efficient fuel that has made the auto, the airplane and the motor boat possible. We should not know how to get along without the paraffin, vaseline, lubricating oil and innumerable other petroleum products that enter into our daily life. Mineral oil contains so many such valuable substances that it is a pity to burn it up in running steam engines where other fuels may serve. As petroleum gets scarcer, we may expect to see the burning of the crude oil prohibited.

HOW OLD IS DISEASE?

THERE is a curious belief still lingering in the popular mind that diseases came in with civilization; that primitive men and animals lived in a state of perpetual health and died a natural death—though it is hard to see what is meant by "natural" in this sense. Even Mrs. Charlotte Perkins Gilman, who is very much of a modernist, falls into this folk fallacy, for in her poem on "the little Eohippus" she makes the cave-man prophesy:

> We are going to wear great piles
> of stuff
> Outside our proper skins!
> We are going to have diseases!
> And accomplishments!! and
> sins!!!

"It was a clinching argument to the Neolithic mind," but really it was not so. The Neolithic man was all too familiar with diseases and doubtless had also his accomplishments and sins. He suffered from rheumatism and "cave gout" and toothache, for caverns are damp and chilly lodgings. He shared the diseases as he did the lodgings of the cave bear and saber-toothed cats. The earliest human bones, if indeed they can be called human—those of the ape-man who lived in Java some half million years ago, bears the marks of a painful malady. The skull of the Dawn Man of Piltdown, England, a hundred thousand years old, is deformed by disease.

The men of the Stone Age must have suffered frightfully from headache for they allowed the tribal doctor to cut holes in their skulls with flint knives to let out the demon that was causing the pain. And if the patient was not cured or killed by this treatment he sometimes tried it again when he had another headache. Dr. Roy L. Moodie, of the University of Chicago, in his new book, "The Antiquity of Disease," says: "A few ancient skulls reveal five cruel operations, which had all healed. The patient had survived them all." But he suggests that since this custom of trepanning was practiced most commonly in Peru the patient may have had the relief of a local anesthetic in the form of a few leaves of coca, the plant that gives us cocaine.

But eons before the human era the dumb animals had to endure all manner of diseases. The dinosaurs of the Mesozoic Era had "misery in the bones"—and such bones as they were! You have seen them in the museum. It must have been worse than a giraffe's sore throat. "Pott's disease" was doing its wicked work millions of years before Dr. Pott was born, though this sounds like an anachronism. This is shown by the discovery of backbones of saurians that had been stiffened by tuberculosis. Tumors are to be seen on reptile skeletons buried in the rock chalk of Kansas, and broken bones showing signs of bacterial infection have been found as far back as the Permian of Texas.

Geologists have to depend mostly upon bones for their knowledge of ancient diseases since the softer parts do not leave fossil remains, but the stems of crinoids in the coal fields are found bored into by worms and it is apparent that the mollusks,

crustaceans and plants of earlier ages were afflicted with parasites and other pests.

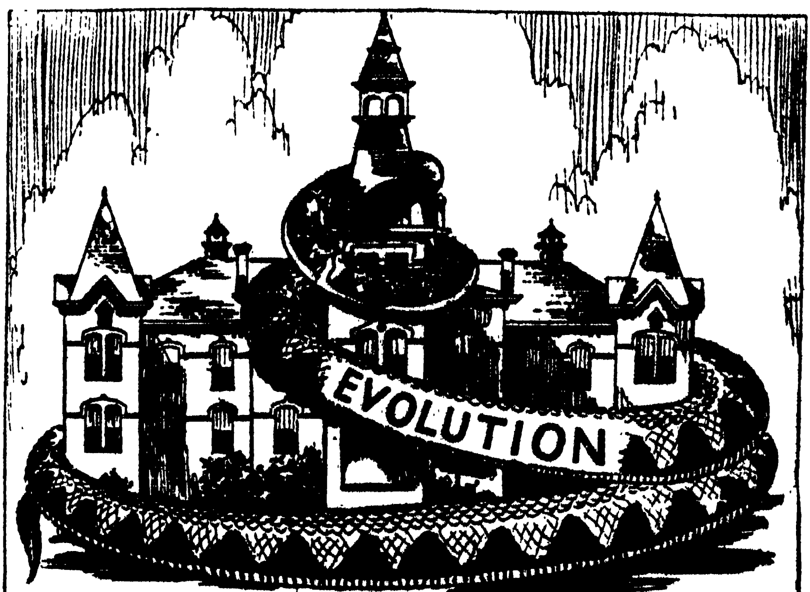
The earliest and simplest forms of plant and animal life, the bacteria and protozoa, seem envious of later arrivals and wage perpetual war on them to this day. The larger animals prey upon the smaller, but so do the smaller upon the larger, and the most dangerous of beasts of prey are the littlest. When man appeared on the planet he found the microbe lying in wait for him. Sooner or later, we all fall victims to the lower forms of life, and, after death, if not before, become the food of our invisible enemies. Even Tut-Ankh-Amen, embalmed and entombed for the perpetual preservation of his personality, will ultimately be gathered into the recurrent cycles of common life.

SCIENTIFIC ITEMS

We record with regret the death of Arthur Gordon Webster, for more than thirty years professor of physics in Clark University; of Schuyler Skaats Wheeler, president of the Crocker-Wheeler Company of New York, distinguished as an electrical engineer; of John Venn, president of Caius College, Cambridge, eminent for his work on logic and later for his archeological researches, and of Charles Emmanuel Forsyth Major, the English paleontologist.

At the meeting of the National Academy of Sciences held in Washington on April 25, Dr. A. A. Michelson, professor of physics in the University of Chicago, was elected president in succession to Dr. Charles D. Walcott, secretary of the Smithsonian Institution. Dr. J. C. Merriam, president of the Carnegie Institution of Washington, was elected vice-president in succession to Dr. Michelson.

Sir David Bruce has been nominated by the council as president of the British Association for the Advancement of Science at its meeting next year in Toronto.



EVOLUTION AND THE SCHOOL
as seen by the *Dallas Morning News* for April 17, 1923, before the meeting of the Fundamentalist Conference at Fort Worth, Texas.

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